MITSUBISHI ELECTRIC

# POWER LOSS SIMULATION

**Ver.5**

## User's Manual

Publication Date: April 2014

Application Note DPH-9451-A



MITSUBISHI ELECTRIC CORPORATION

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# 1 Introduction

## 1.1 Features of Mitsubishi Power Module Loss Simulator

The power loss simulation software for inverter systems referred in this document is named "Melcosim".

## 1.2 Hardware Requirements

(1) OS
Microsoft® Windows® Windows7 Professional(32bit, 64bit)

(2) HDD
50MB or more (except Microsoft® .NET Framework).

(3) Memory
500MB or more

(4) Library
Microsoft .NET Framework3.5 or later

## 1.3 Definition

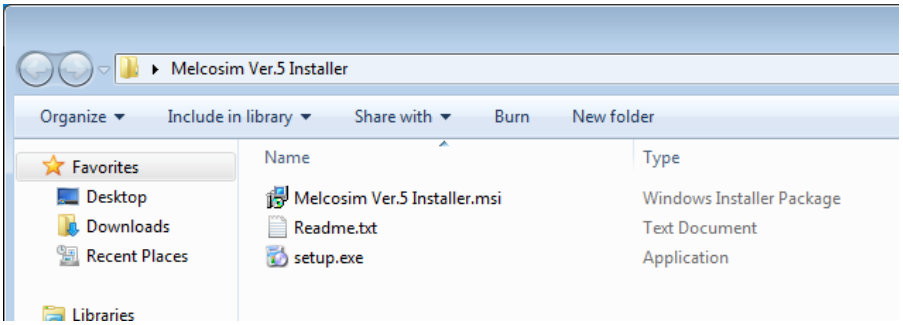
This document explains the operation of the Mitsubishi Power Module Loss Simulator "Melcosim" for 2Level inverter and 3-Level inverter.

* Windows is a registered trademark of Microsoft Corporation in the United States and other countries.
Mitsubishi Power Module Loss Simulator is a Microsoft .NET Framework-based application

## 1.4 Installation

### 1.4.1 Decompression

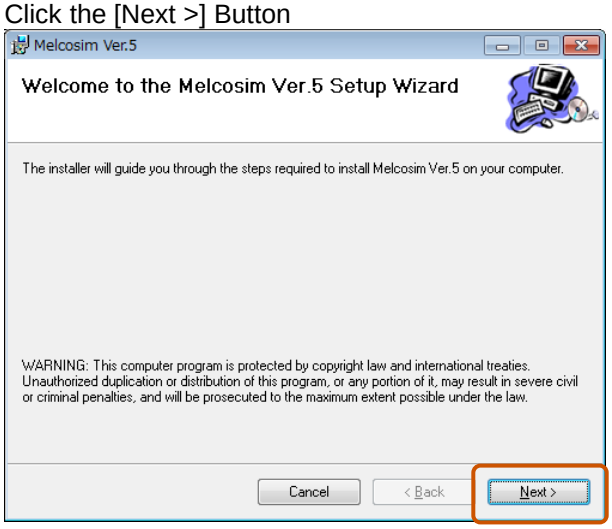
Download from the Mitsubishi Electric Homepage and decompress "Melcosim Ver.5 Installer.zip" into an arbitrary folder.
The downloaded ZIP file should contain three :
- Melcosim Ver.5 Installer.msi
- Readme.txt
- setup.exe



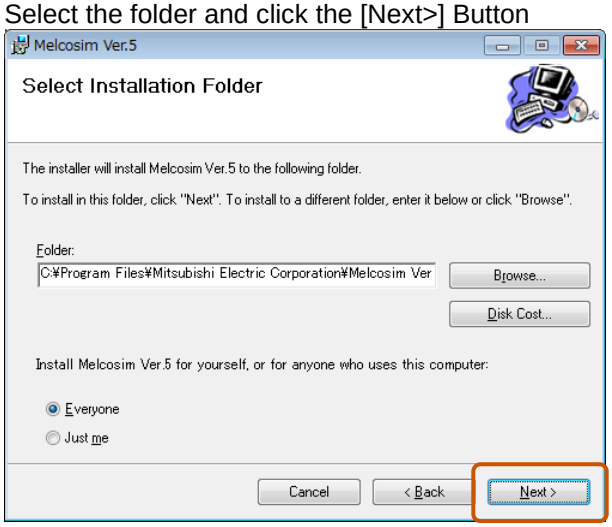
### 1.4.2 Setup

Execute "setup.exe".

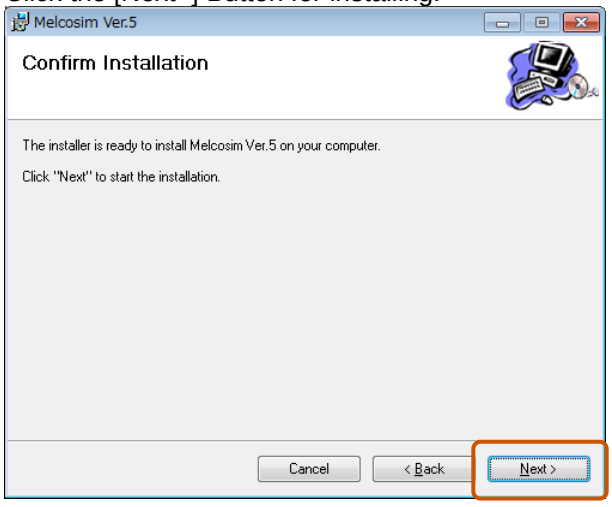
Click the [Next >] Button



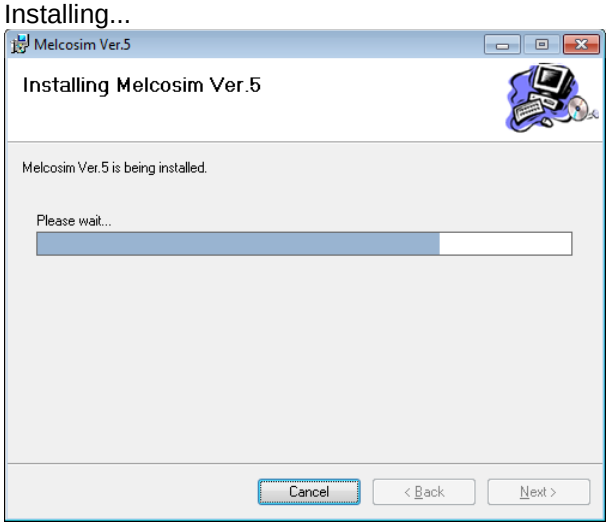

Change the installion folder, if necessary by clicking on “Browse”. (A default folder is proposed under "Program Files".
Select the folder and click the [Next>] Button



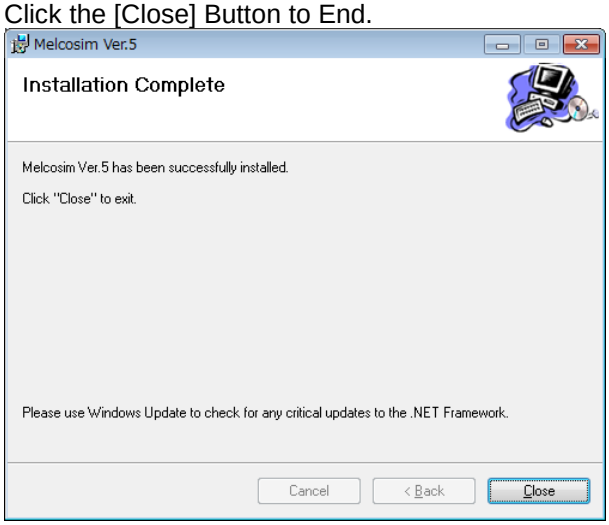

Click the [Next>] Button for installing.



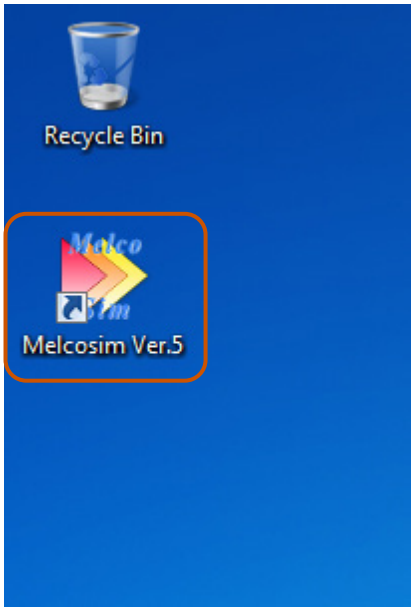
Installing...

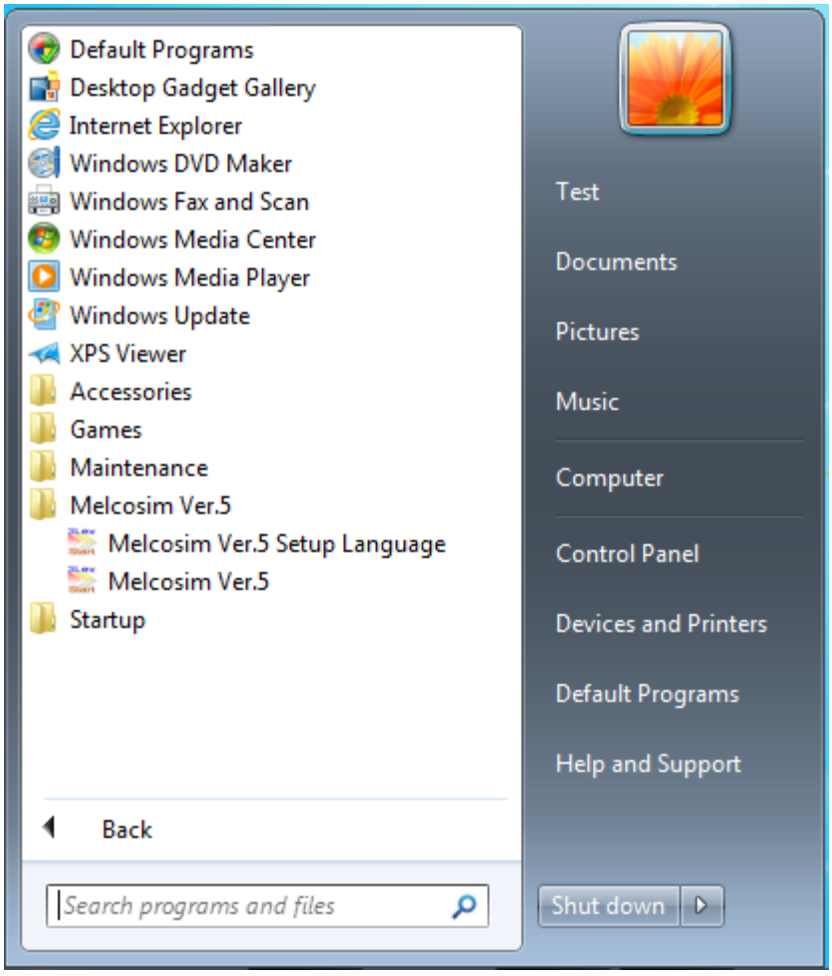



Click the [Close] Button to End.



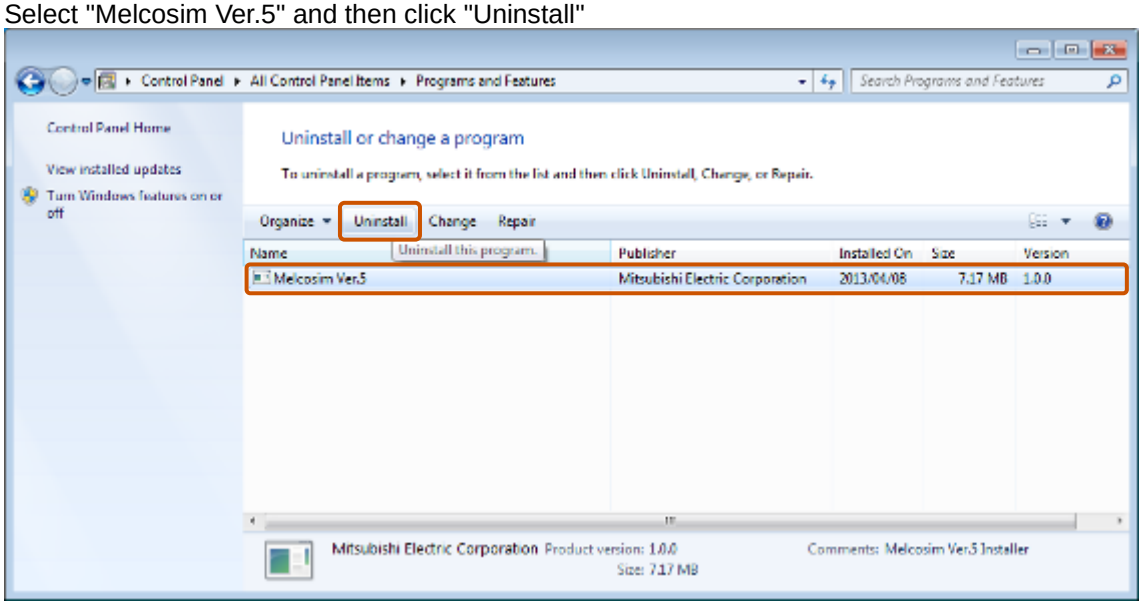
A short-cut Icon for the Melcosim Ver.5 will be generated on the Desktop after installation.



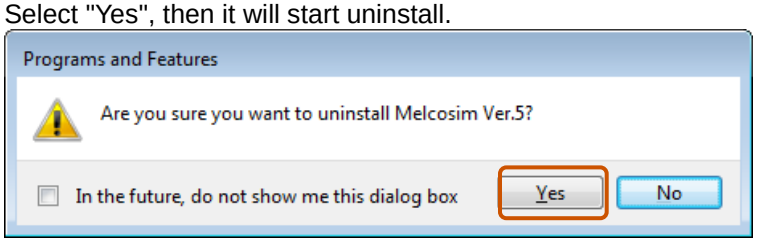



## 1.5 Uninstallation

Select "Programs and Features" in Windows menu "Control Panel".
Select "Melcosim Ver.5" and then click "Uninstall"




Select "Yes", then it will start uninstall.




After the uninstallation, please confirm to erase " Melcosim Ver.5".

# 2 Description of the Windows

## 2.1 Interface language setup

This software selects the interface language out ofseven languages by using "PowerLossSimLangSetting.exe".

### 2.1.1 Language options

The following languages are available:

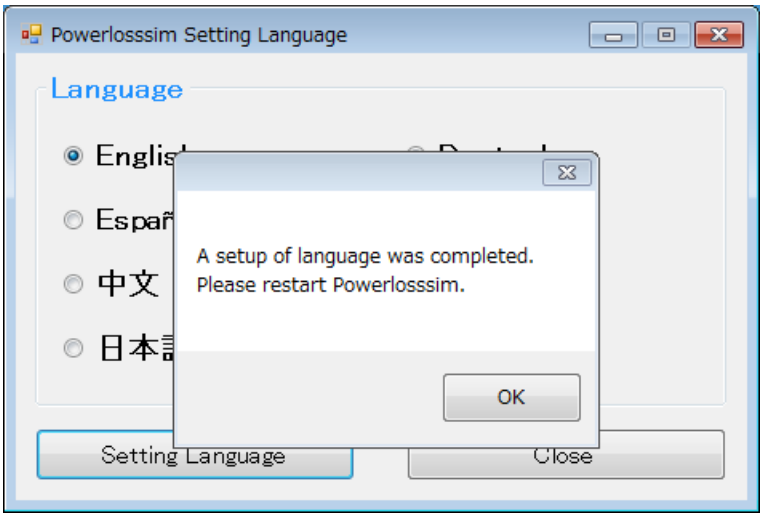
- English (default)
- Japanese
- German
- Chinese
- Spanish
- Portuguese
- Korean

### 2.1.2 Selecting the language

Click "Melcosim Ver.5 Setup Language" in the Start Menu for executing "PowerLossSimLangSetting.exe" which starts the language selection tool.


Select your preferred language.

Click the the [OK] button of the dialog box and click the [Close] button of the ""PowerLossSimLangSetting.exe".



### 2.1.3 Language selection timing

The language setup program "PowerLossSimLangSetting.exe" can be executed regardless if "Melcosim" is already running or not. Hence, the language selection tool can be started at any time to change the current language.

## 2.2 Main window

The shown main window of Melcosim informs the actually installed version of the User Guide and Software version information. It furthermore provides the selection options for the type of new design on the left side of the screen and also a small file manager providing easy access to recently opened files.


**(1) [2 Level New Design]**
New 2 Level simulation (refer to 2.4).

**(2) [3 Level New Design]**
New 3 Level simulation (refer to 2.5).

**(3) [Open English User Guide]**
Access to the English User's Manual.

**(4) [Open Japanese User Guide]**
Access to the Japanese User's Manual

**(5) [About Melcosim]**
Confirm version of this software and data (refer to 2.3).

**(6) [Design1]**
Read latest stored calculation conditions.
Include 2 Level conditions and 3 Level conditions.

**(7) [Design2]**
Read second latest stored calculation conditions.

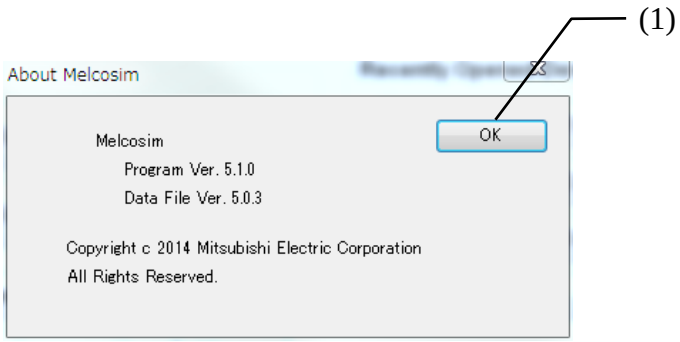
**(8) [Design3]**
Read third latest stored calculation conditions.

**(9) [Open]**
Open other stored calculation conditions from selecting window.

**(10) [Close]**
Exit simulator (Close all windows).

## 2.3 Version

This screen confirms the program version and the data file version.

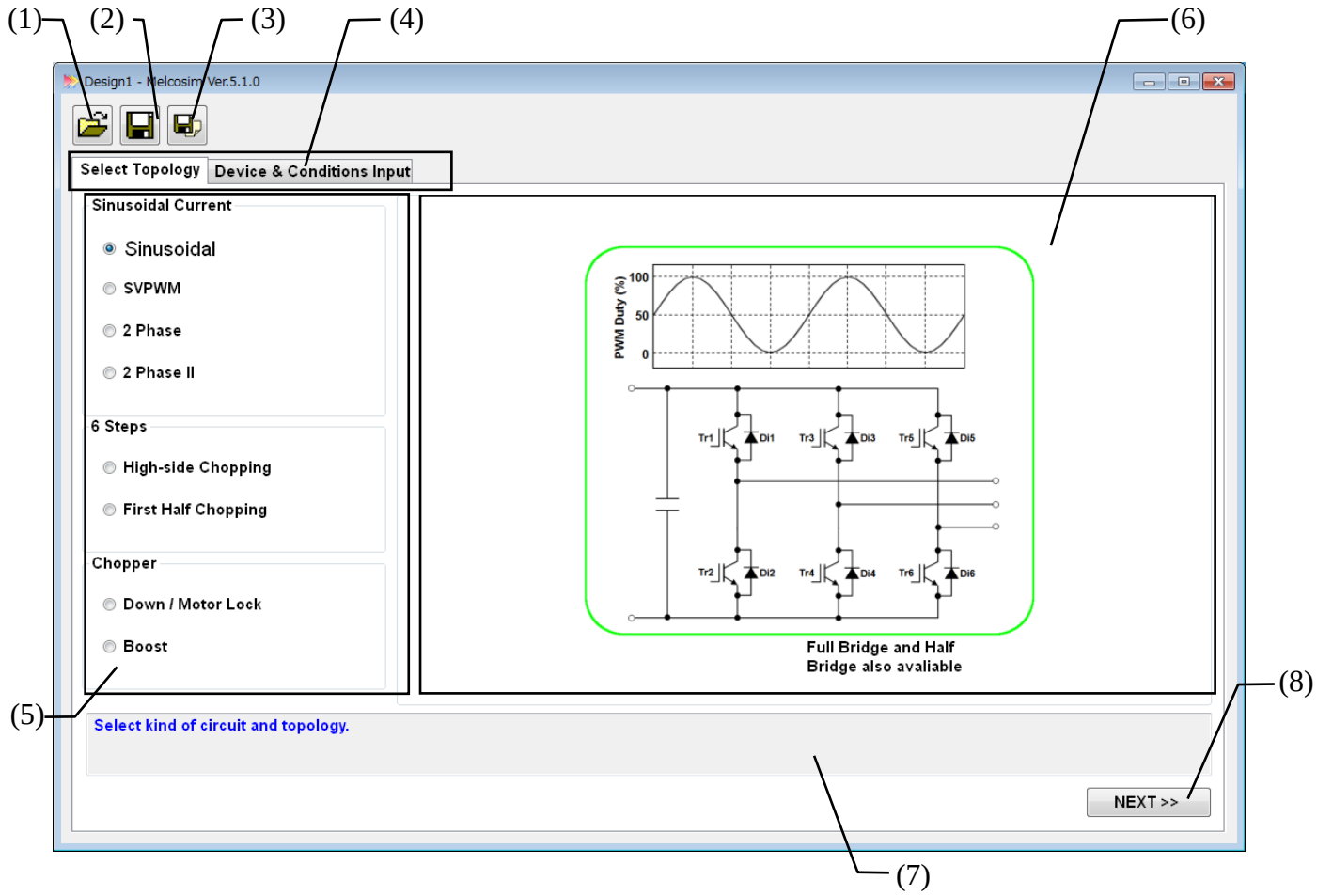



**(1)[OK]**
Close this window.

## 2.4 Power loss simulation (2 Level)

### 2.4.1 2Level topology selection window

Bellows screen shows the window for selecting the topology topology.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from the next popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Select window

**(5) [Topology and modulation technique] selction**
Select a suitable calculation method for the used topology.
(refer to 7)

**(6) [Selected Topology] structure**
Show the selected topology and schematic.

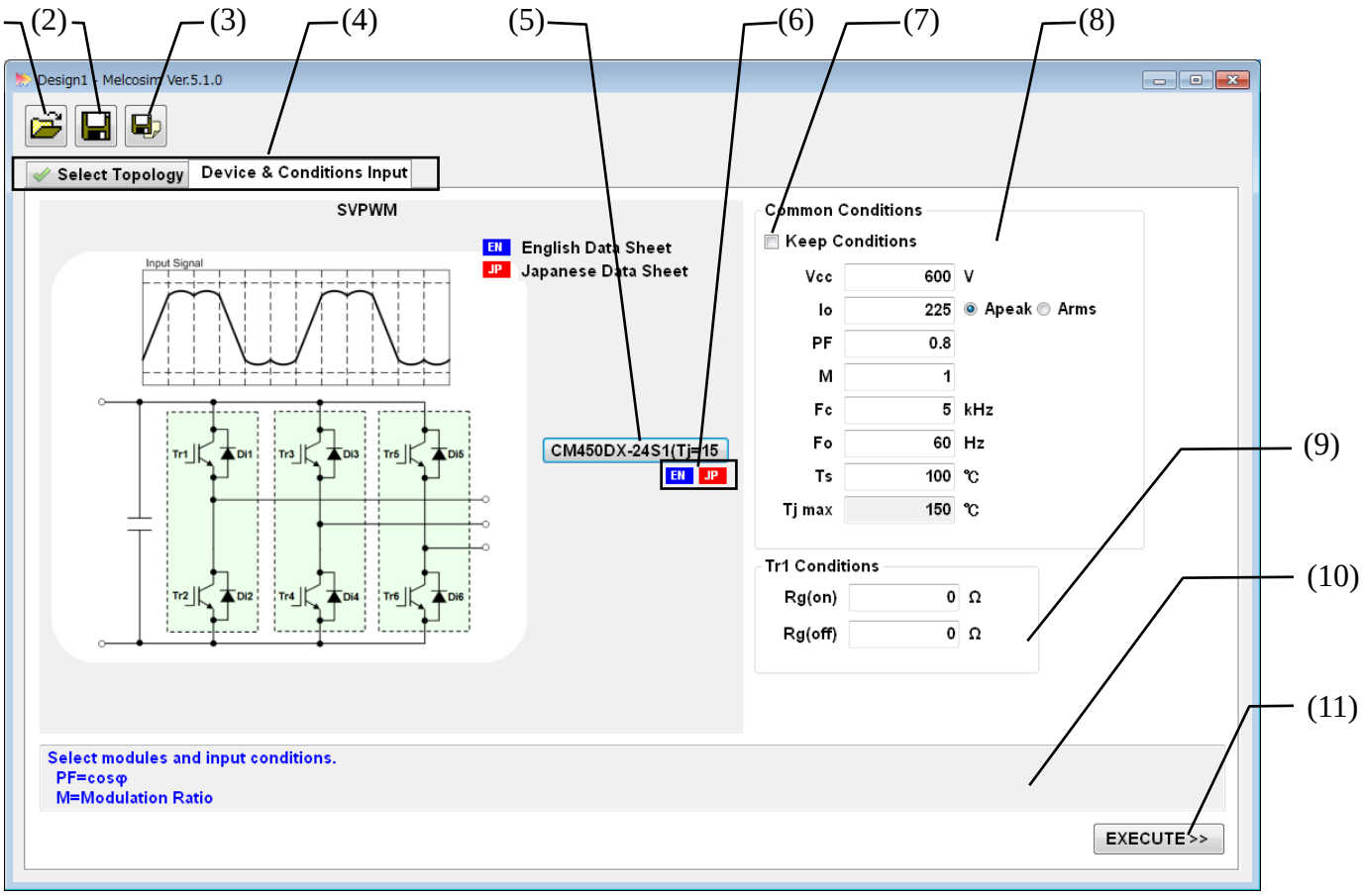
**(7) [Comment]**
Comment for this window.

**(8) [NEXT]Button (Ctrl + N)**
Set a selected topology and jump to the "Device & Conditions Input" TAB (refer to 2.4.2).

(*1) Selected algorithm is emphasized.

### 2.4.2 2Level device & conditions input window

Select Power Modules and input parameters for the power loss calculation.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from a popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as new file.

**(4) [Stage]TAB**
Select Window.

**(5) [Select Module]**
Open a selection window (refer to 2.4.3).

**(6) [Link to Data sheet]**
Download the datasheet of the selected module from WEB site. (internet connection required).

**(7) [Keep Conditions] Check Box**
Freezing common conditions when this box is checked.
(These common conditions are maintained when re-selecting a module.)

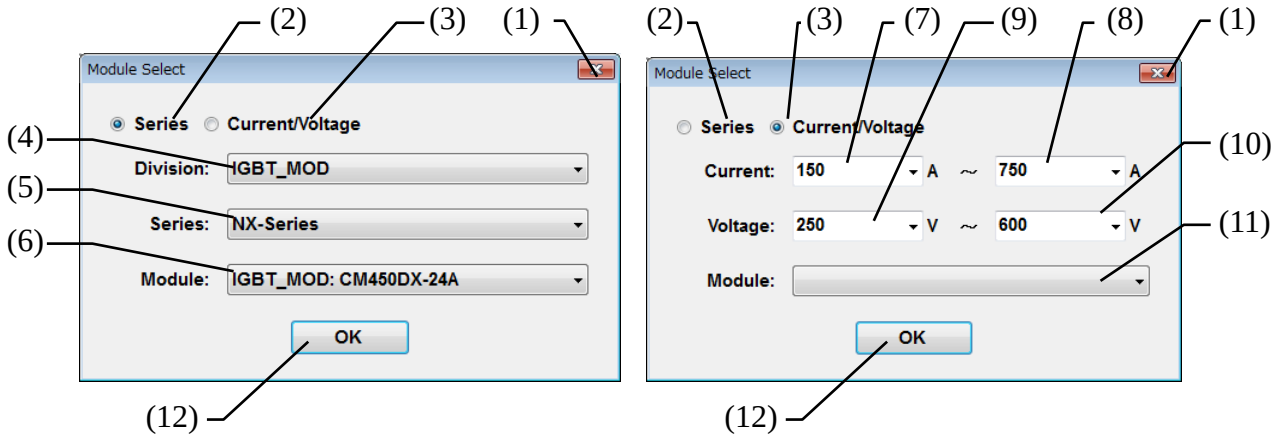
**(8) [Common Conditions]**
Set common conditions

**(9) [Tr1 Conditions] - [Tr2 Conditions]**
Set Gate resistor value.
Gate resistance of Tr1 is same as Tr2 to Tr6 in Sinusoidal, SVPWM, 2 phase, 2phase II and First-half chopping topology.
Gate resistance of Tr1 is same as Tr3 and Tr5, gate rresistance of Tr2 is same as Tr4 and Tr6 for 1in1 device in High-side chopping.
Default data are input after selecting the module.
These fields are invalid for IPMs.

**(10) [Comment]**
Comment for this window.

**(11) [EXECUTE] (Ctrl + E)**
Execute calculation and jump to the [Result] TAB (refer to 2.4.4)
with generating the [Graph] TAB (refer to 2.4.5).

### 2.4.3 Module selection window




**(1) [×] (ESC)**
Close this window without module selection.

**(2) [Series]**
Module selection through module series (left window)

**(3) [Current/Voltage]**
Module selection through current/voltage ratings (right window)

**[Series] Selection through the IGBT/IPM series**

**(4) [Division]**
Select Division (IGBT , IPM etc.) (*1)

**(5) [Series]**
Select Series (NX-series, A-series etc.) (*1)

**(6) [Module]**
Select target module

**[Current/Voltage] Selection through the current / voltage rating**

**(7) [Current Min]**
Chose minimum value of Current rating. (*1)

**(8) [Current Max]**
Chose maximum value of Current rating. (*1)

**(9) [Voltage Min]**
Chose minimum value of Voltage rating. (*1)

**(10) [Voltage Max]**
Chose maximum value of Voltage rating. (*1)

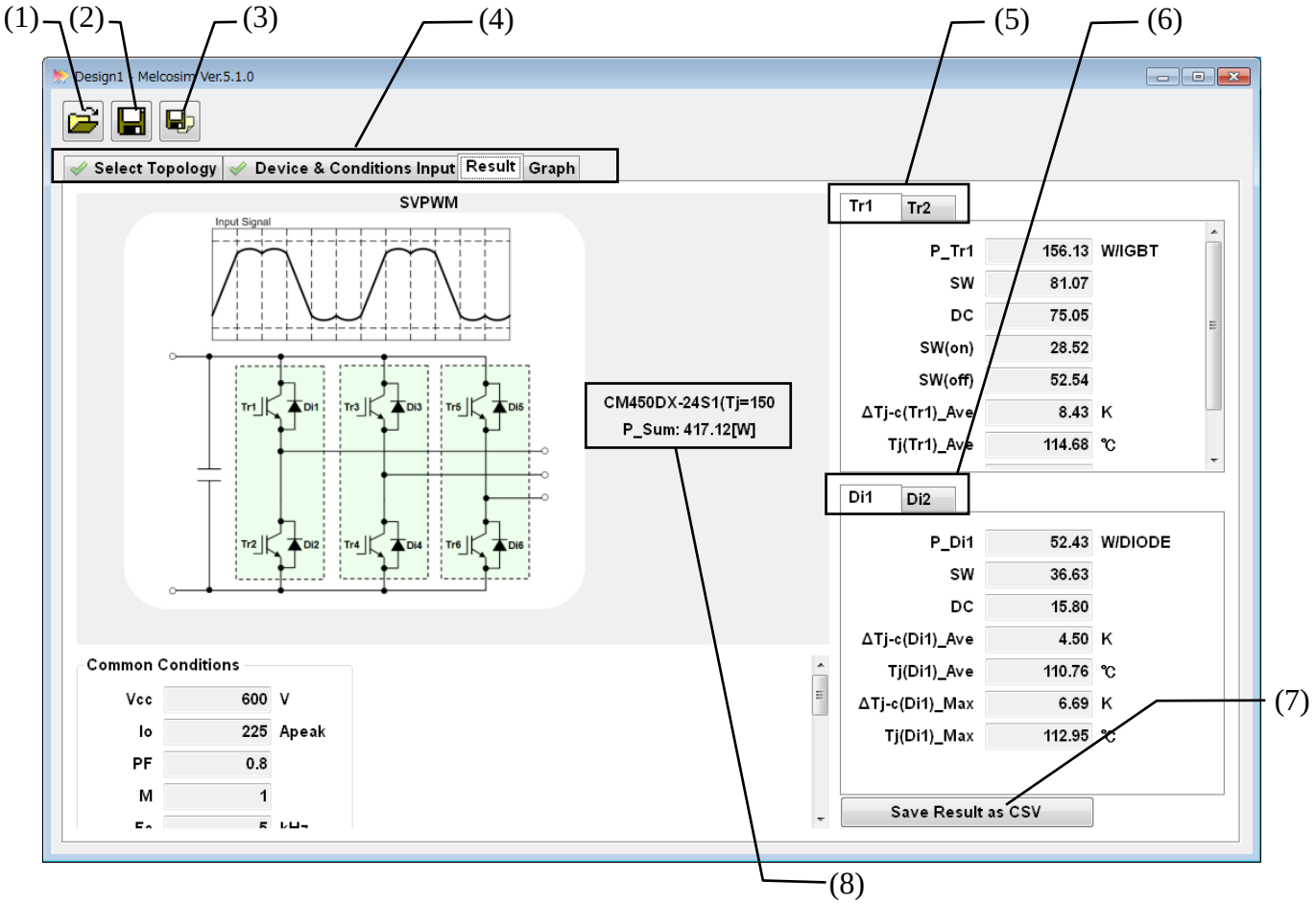
**(11) [Module]**
Select target module.

**(12) [OK]**
Confirm the target module.

*1: Applicable module types in (6) or (11) are refined by each input.

### 2.4.4 2Level result window

The calculation results are shown in this window along with the input calculation conditions.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from a popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Select window.

**(5) [Transistor (IGBT/MOSFET)] TAB**
Simulation result for each Transistor.
Display the result for each Transistor by selecting TAB.

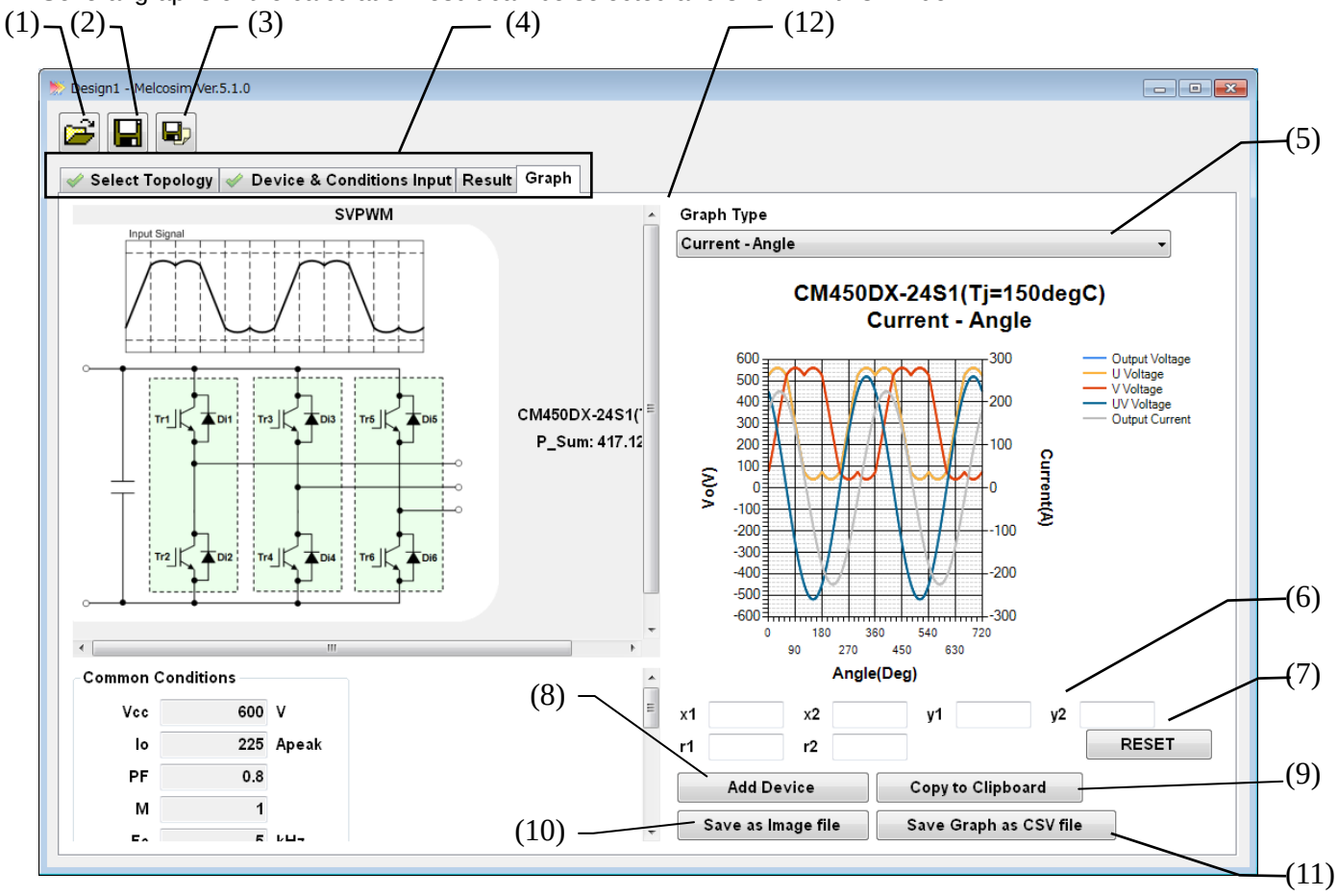
**(6) [Diode] TAB**
Simulation result for each Diode
Display the result for each Diode by selecting TAB.

**(7) [Save Result as CSV]**
Save calculation result in "CSV" format.

**(8) [Module]**
Simulation result for each Module(Inverter part).

### 2.4.5 2Level graph window

Several graphs of the calculation result can be selected and shown in this window.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from a popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Selection window.

**(5) [Graph Type] List Box**
Selection of graph type (data combinations)
1: Current - Angle
2: Power Loss - Time
3: Power Loss - Current
4: Current (max) - fc
5: Temperature (ave.) - Current
6: Temperature ripple - Time
7: Temperature Rise (ave.& max.) - Current
8: Io(A), P(W) - Time
9: Io(A), P(W) - Angle
10: Tc(max) - Current

**(6) [Set Range]**
Set MIN and MAX of x-Axis, y-Axis and y2(right)-Axis.
Manual zooming by Click and Drag on the graph are available.

**(7) [RESET]**
Reset range setting and zooming.

**(8) [Add Device]**
Add or remove elements of the modulefor the graph.
(refer to 2.4.6)

**(9) [Copy to Clipboard]**
Copy the graph to clipboard in "PNG" format.

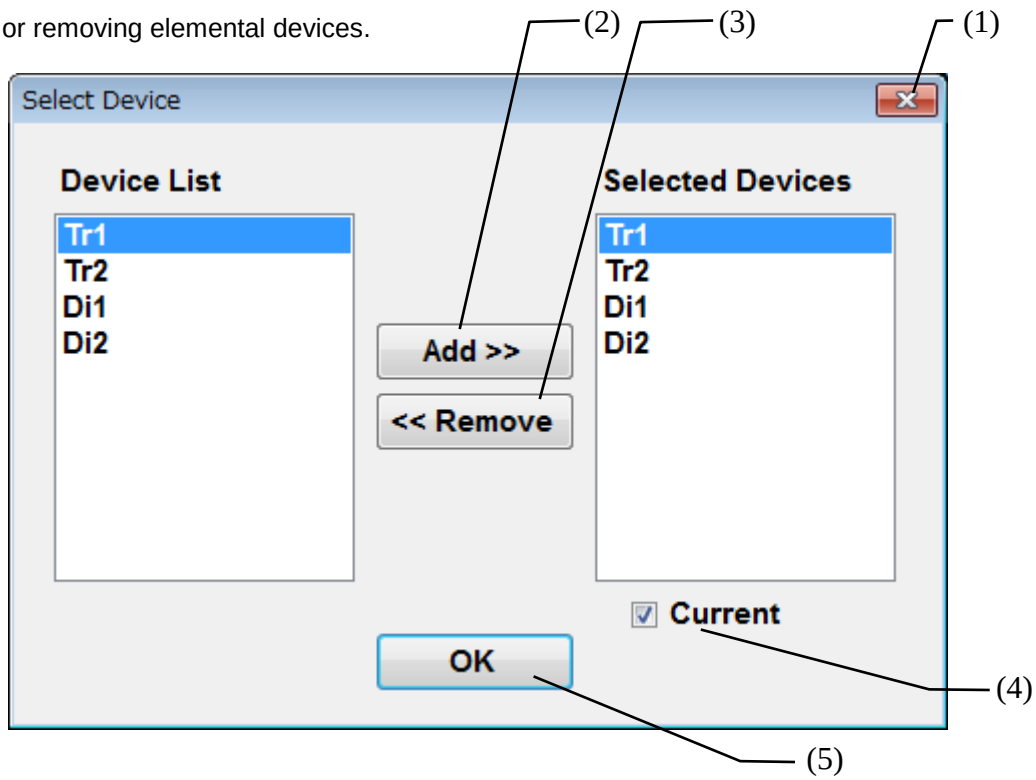
**(10) [Save as Image file]**
Save the graph in "PNG" format.
(refer to 2.4.7)

**(11) [Save Graph as CSV file]**
Save graph data in "CSV" format.

**(12) [Expand Graph Area]**
Click this area and move scroll bar for expanding graph width.
Maximize window and expand graph width is recommended for getting better graph resolution.

### 2.4.6 Add device

Select adding or removing elemental devices.




**(1) [×] (ESC)**
Cancel device's element selection

**(2) [Add]**
Add elements of the device from the device list.

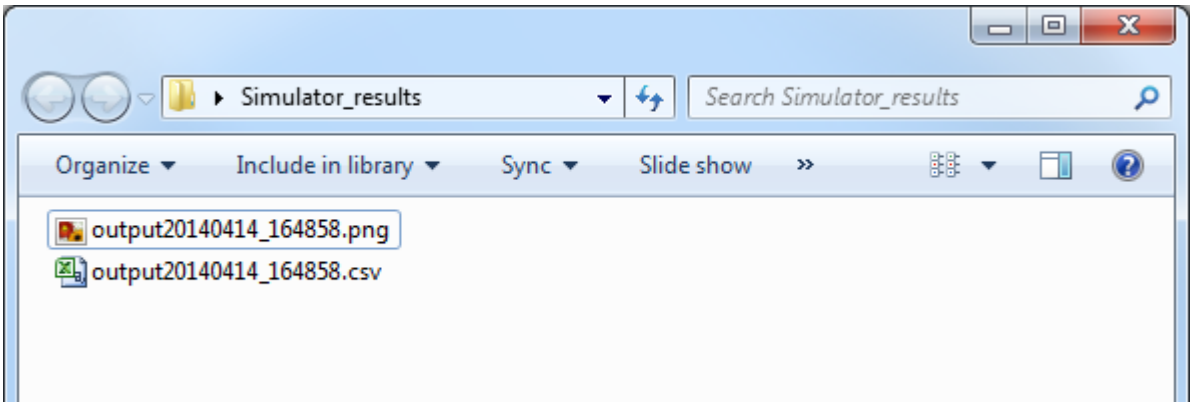
**(3) [Remove]**
Remove elements of the device from the selected devices list.

**(4) [Current]**
With Io waveform for phase angle confirmation.

**(5) [OK]**
Confirm selection.

### 2.4.7 Save as Image file

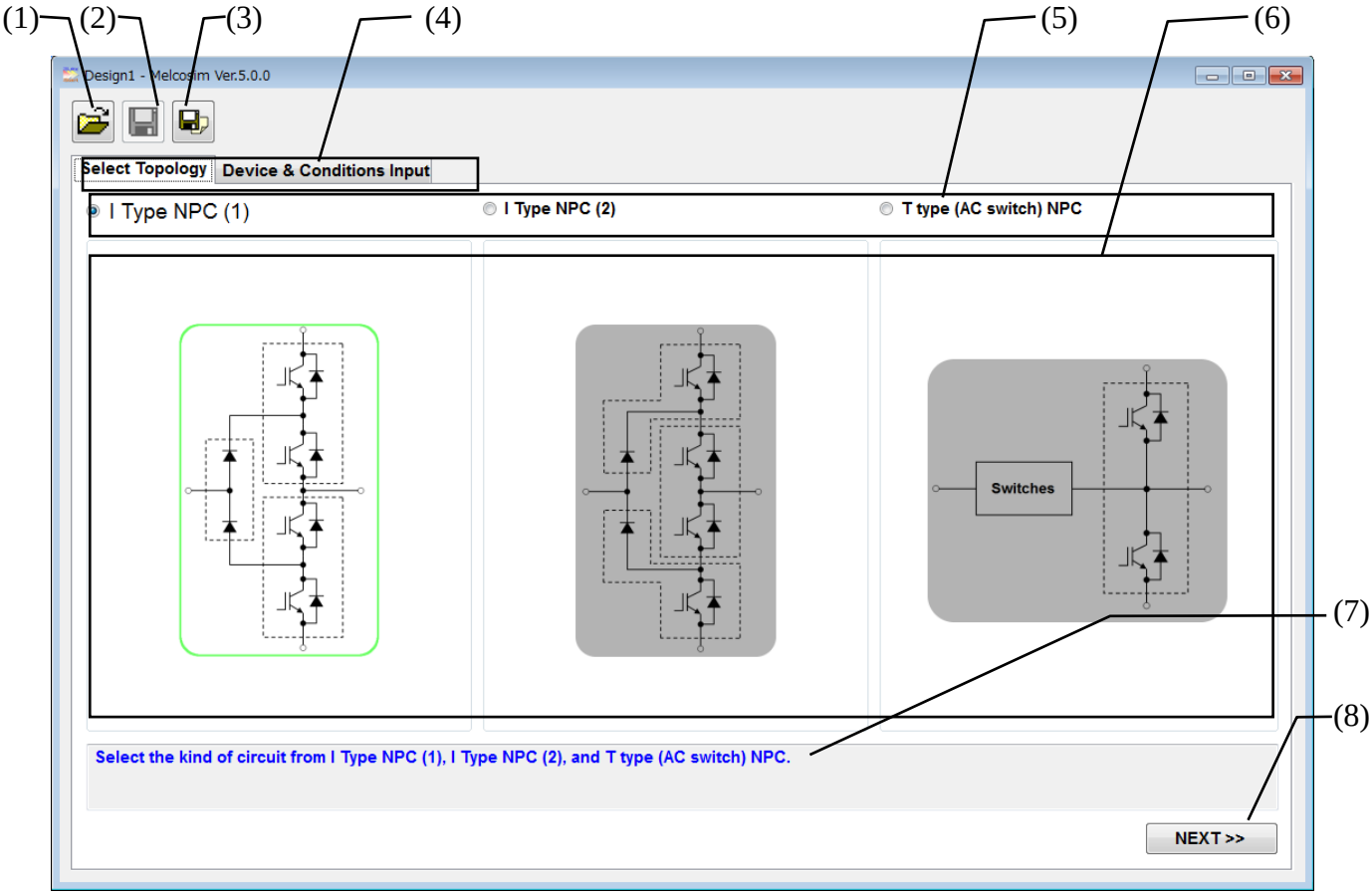
Save the graph in "PNG" format with simulation condition data in same name "CSV" file.



## 2.5 Power loss simulation (3 Level)

### 2.5.1 3Level topology selection

Bellows screen shows the window for selecting the topology topology.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from a popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Select window.

**(5) [Topology]**
Click on the button or schematic area to select the calculation topology (*1)

**(6) [Schematic]**
Click on the button or schematic area to select the calculation topology. (*1)

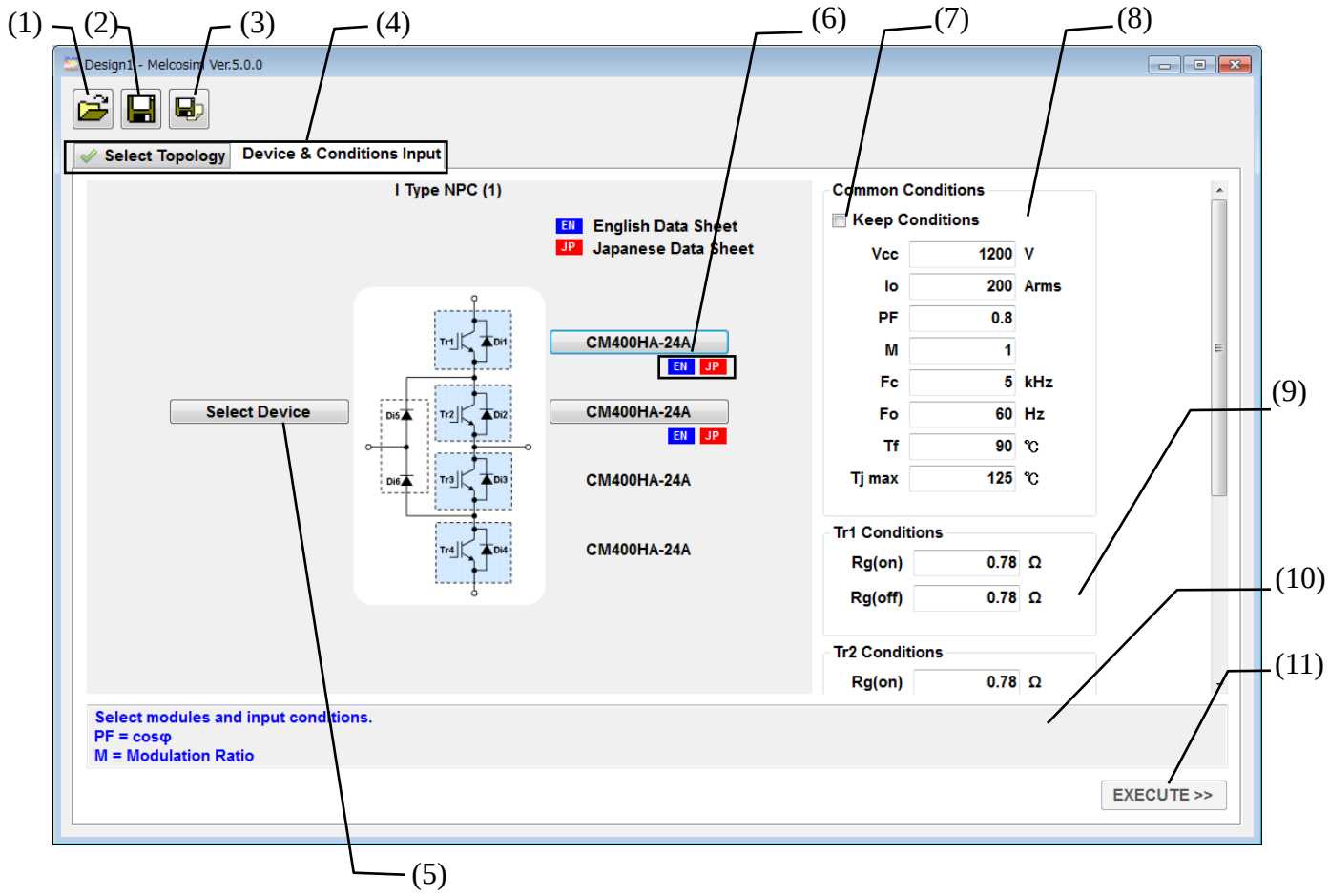
**(7) [Comment]**
Comment for this window.

**(8) [NEXT>>] (Ctrl + N)**
Set a selected topology and jump to the "Device & Conditions Input" TAB. (refer to 2.5.2)

(*1) Selected circuit name and schematic displays are emphasized.

### 2.5.2 3Level device & conditions input window

Selection of the Mitsubishi Power Modules and input parameters for the loss calculation.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Select Window.

**(5) [Select Module]**
Open a selection window (refer to 2.5.3)

**(6) [Link to Data sheet]**
Download the datasheet of the selected module from WEB site. (internet connection needed).

**(7) [Keep Conditions] Check Box**
Freezing common conditions when this box is checked.
(These common conditions are maintained when re-selecting a module.)

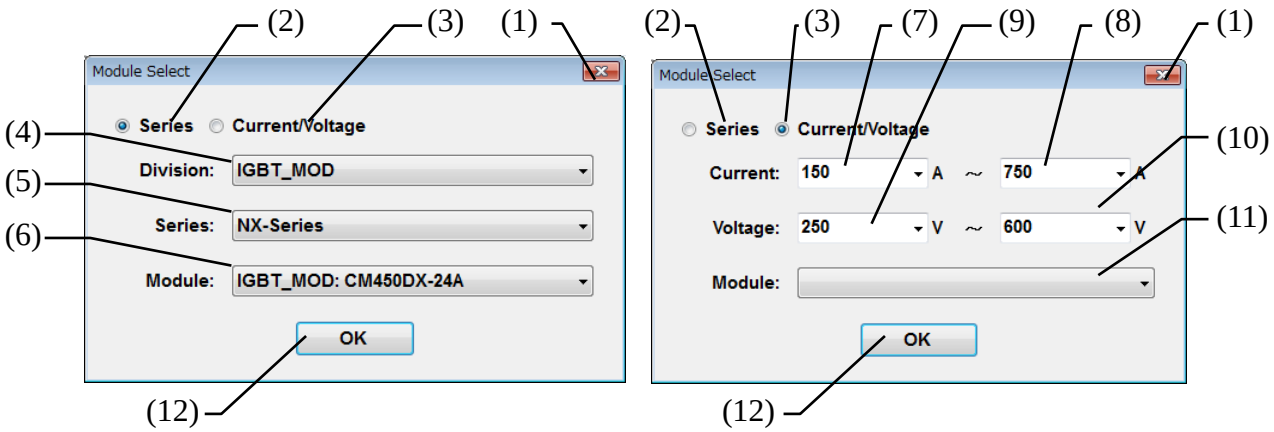
**(8) [Common Conditions]**
Set common conditions

**(9) [Tr1 Conditions] – [Tr4 Conditions]**
Set Gate resistances
Gate resistances of Tr3 and Tr4 are same as Tr2 and Tr1 respectively.
Default data is input after selecting Tr1 module.

**(10) [Comment]**
Comment for this window.

**(11) [EXECUTE] (Ctrl + E)**
Execute calculation and jump to the [Result] TAB (refer to 2.5.4).
with generating the [Graph] TAB (refer to 2.5.5)

### 2.5.3 Module selection window




**(1) [×] (ESC)**
Close this window without module selection.

**(2) [Series]**
Module selection through module series (left window)

**(3) [Current/Voltage]**
Module selection through current/voltage ratings (right window)

**[Series] Selection through the IGBT/IPM series**

**(4) [Division]**
Select Division (IGBT , IPM etc.) (*1)

**(5) [Series]**
Select Series (NX-series, A-series etc.) (*1)

**(6) [Module]**
Select target module

**[Current/Voltage] Selection through the current / voltage rating**

**(7) [Current Min]**
Chose minimum value of Current rating. (*1)

**(8) [Current Max]**
Chose maximum value of Current rating. (*1)

**(9) [Voltage Min]**
Chose minimum value of Voltage rating. (*1)

**(10) [Voltage Max]**
Chose maximum value of Voltage rating. (*1)

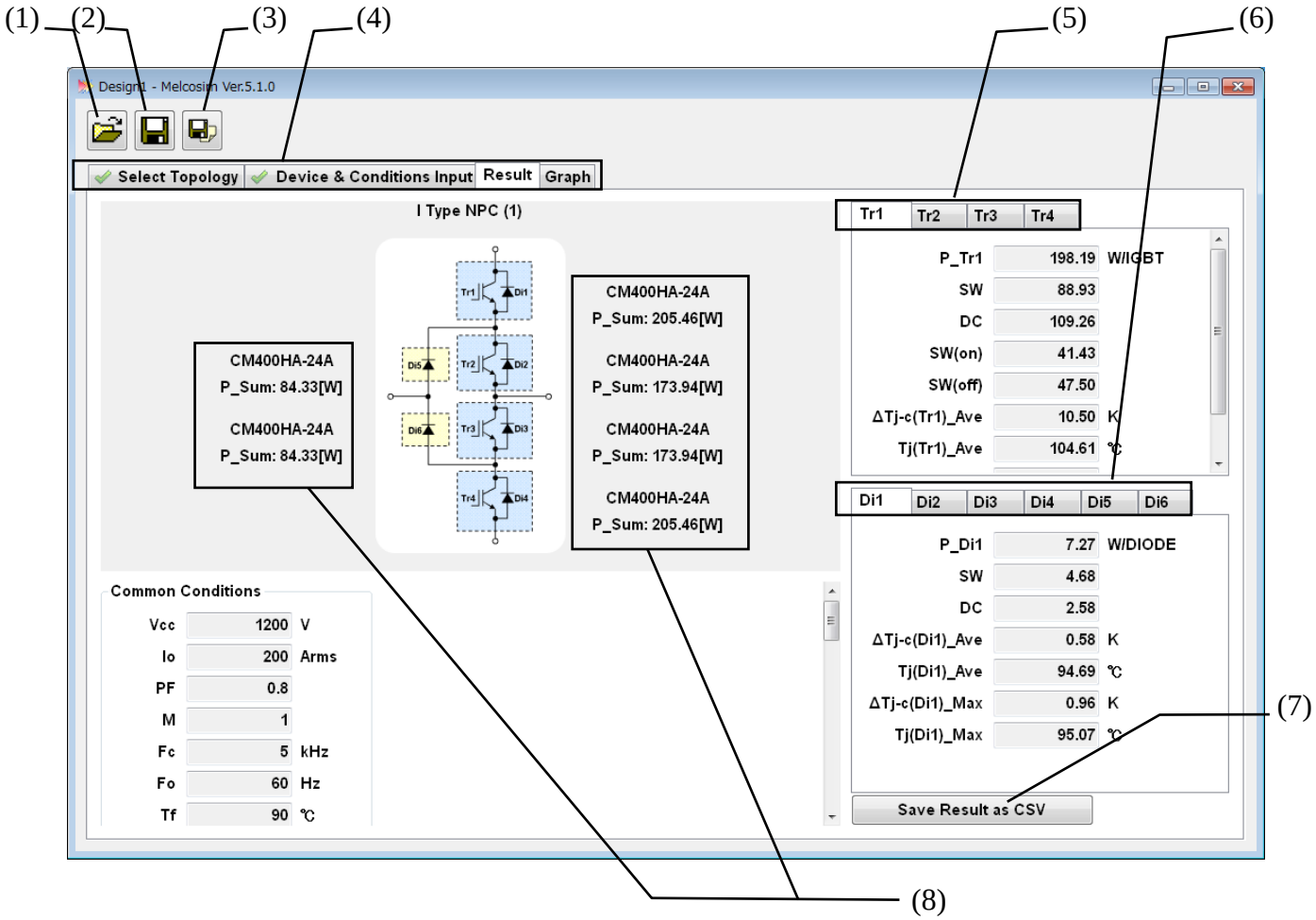
**(11) [Module]**
Select target module.

**(12) [OK]**
Confirm the target module.

*1: Applicable module types in (6) or (11) are refined by each input.

### 2.5.4 3Level result window

The calculation results are shown in this window along with the input calculation conditions.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from a popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Select window.

**(5) [Transistor (IGBT/MOSFET)] TAB**
Simulation result for each Transistor.
Display the result for each Transistor by selecting TAB.

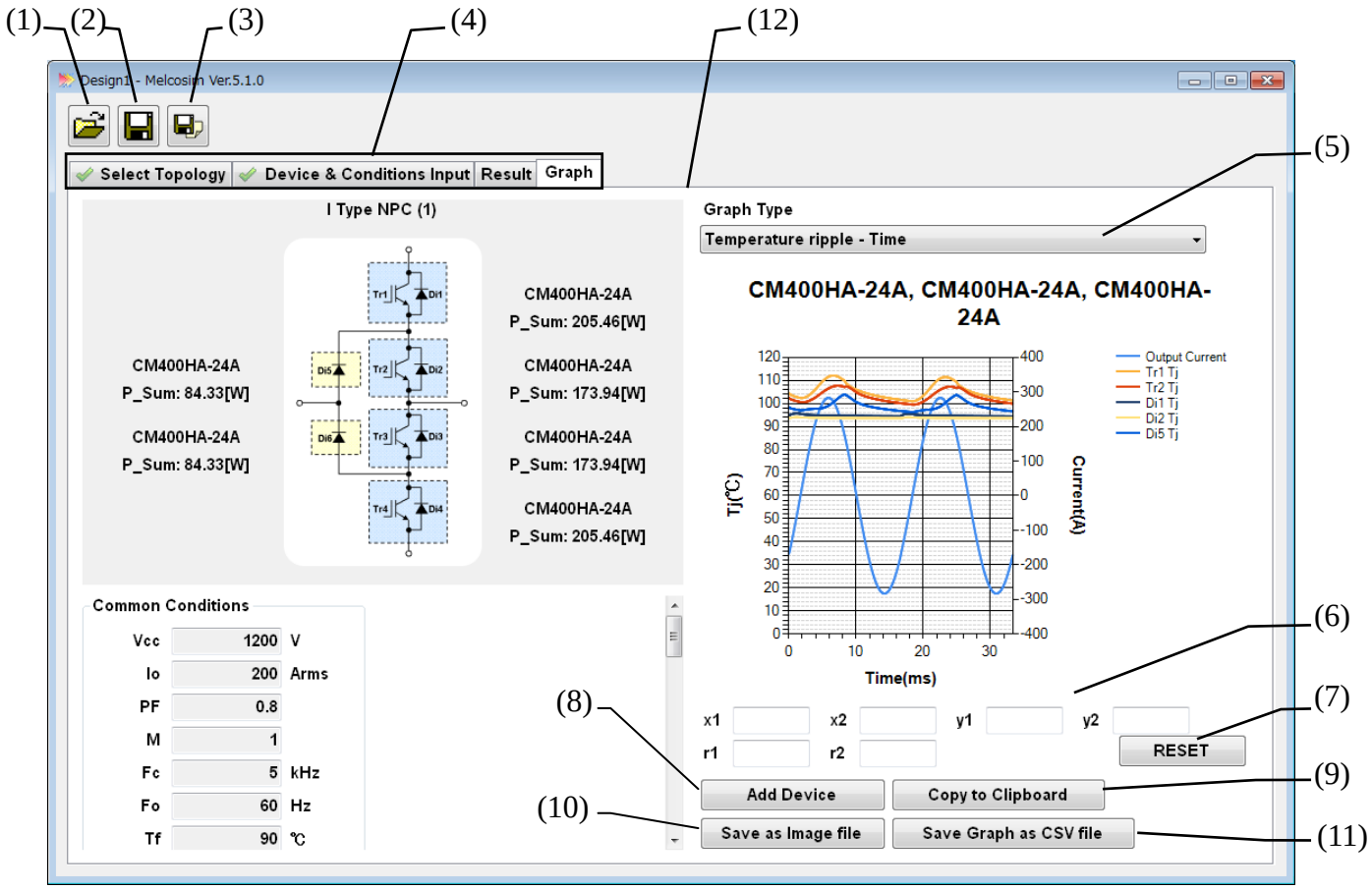
**(6) [Diode] TAB**
Simulation result for each Diode.
Display the result for each Diode by selecting TAB.

**(7) [Save Result as CSV]**
Save calculation result in "CSV" format.

**(8) [Module]**
Simulation result for each Module (Inverter part).

### 2.5.5 3Level graph window

Several graphs of the calculation result can be selected and shown in this window.




**(1) [Open] (Ctrl + O)**
Open stored calculation conditions from a popping up selection window.

**(2) [Save] (Ctrl + S)**
Save calculation conditions.

**(3) [Save As](Ctrl + A)**
Save calculation conditions as a new file.

**(4) [Stage]TAB**
Selection window.

**(5) [Graph Type] List Box**
Select graph type
1: Current - Angle
2: Power Loss - Time
3: Power Loss - Current
4: Current (max) - fc
5: Temperature (ave.) - Current
6: Temperature ripple - Time
7: Temperature Rise (ave.& max.) - Current
8: Io(A), P(W) - Time
9: Io(A), P(W) - Angle
10: Tc(max) - Current

**(6) [Set Range]**
Set MIN and MAX of x-Axis, y-Axis and y2(right)-Axis.
Manual zooming by Click and Drag on the graph are available.

**(7) [RESET]**
Reset range setting and zooming.

**(8) [Add Device]**
Add or remove elemental devices for the graph.
(refer to 2.5.6)

**(9) [Copy to Clipboard]**
Copy the graph to clipboard in "PNG" format.

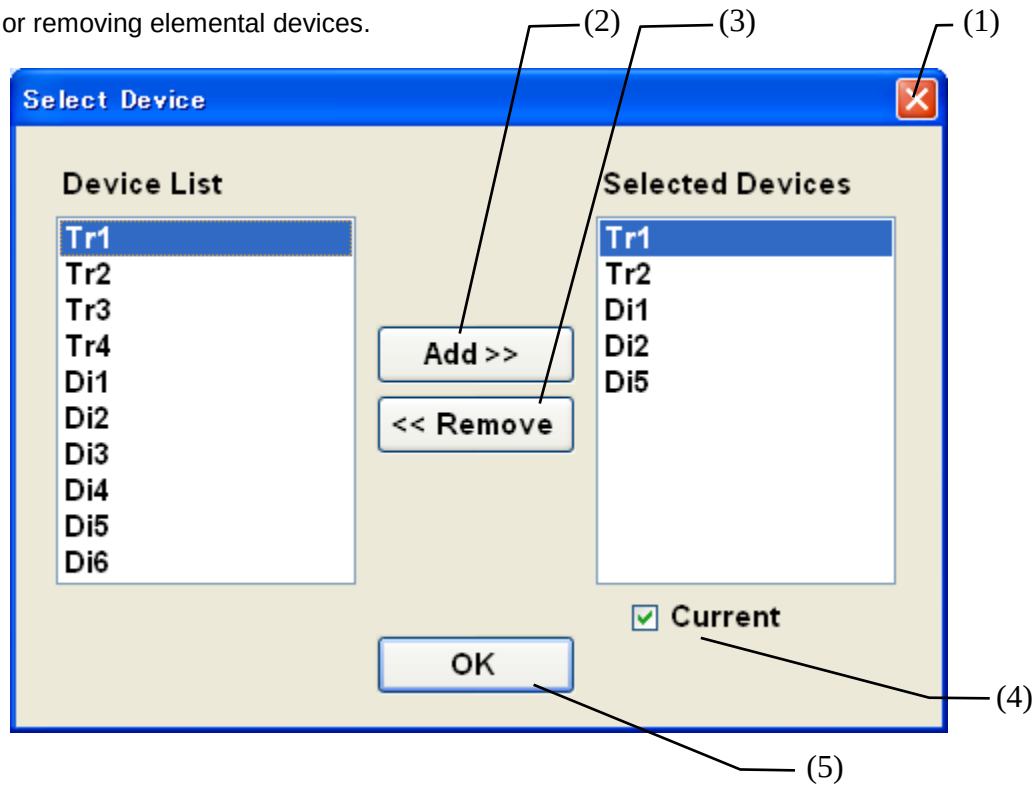
**(10) [Save as Image file]**
Save the graph in "PNG" format.
(refer to 2.5.7)

**(11) [Save Graph as CSV file]**
Save graph data in "CSV" format.

**(12) [Expand Graph Area]**
Click this area and move scroll bar for expanding graph width.
Maximize window and expand graph width is recommended for getting better graph resolution.

### 2.5.6 Add device

Select adding or removing elemental devices.




**(1) [×] (ESC)**
Cancel selecting devices.

**(2) [Add]**
Add elements of the device from the device list.

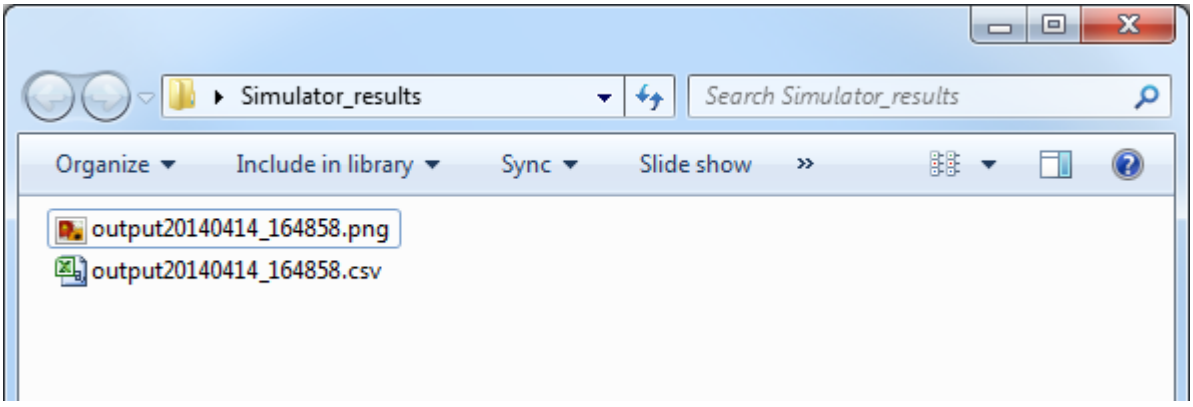
**(3) [Remove]**
Remove elements of the device from the selected devices list.

**(4) [Current]**
With Io waveform for phase angle confirmation.

**(5) [OK]**
Confirm selection.

### 2.5.7 Save as Image file

Save the graph in "PNG" format with simulation condition data in same name "CSV" file.

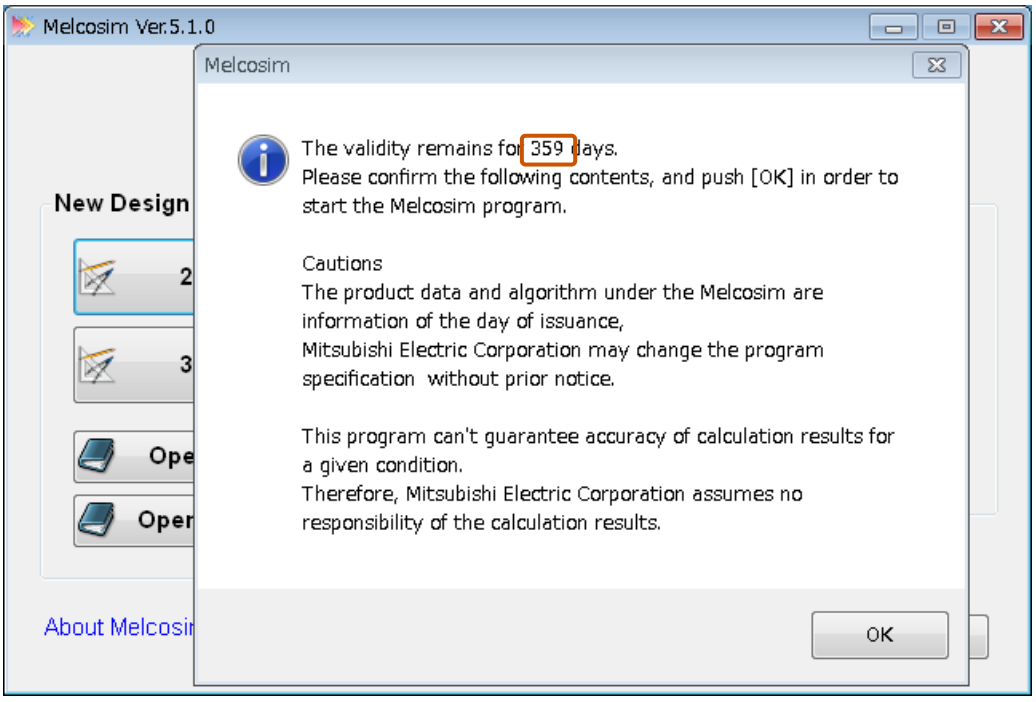


# 3 Procedure for sinusoidal (3 Phase) calculation

Selection of "2 Phase" modulation is carried out by clicking the corresponding button in 3.2.2 for 2 phase modulation. All other procedurer the same as for sinusoidal modulation.

## 3.1 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.




Click OK, then move to the main window in the case that the expiration date is still valid.

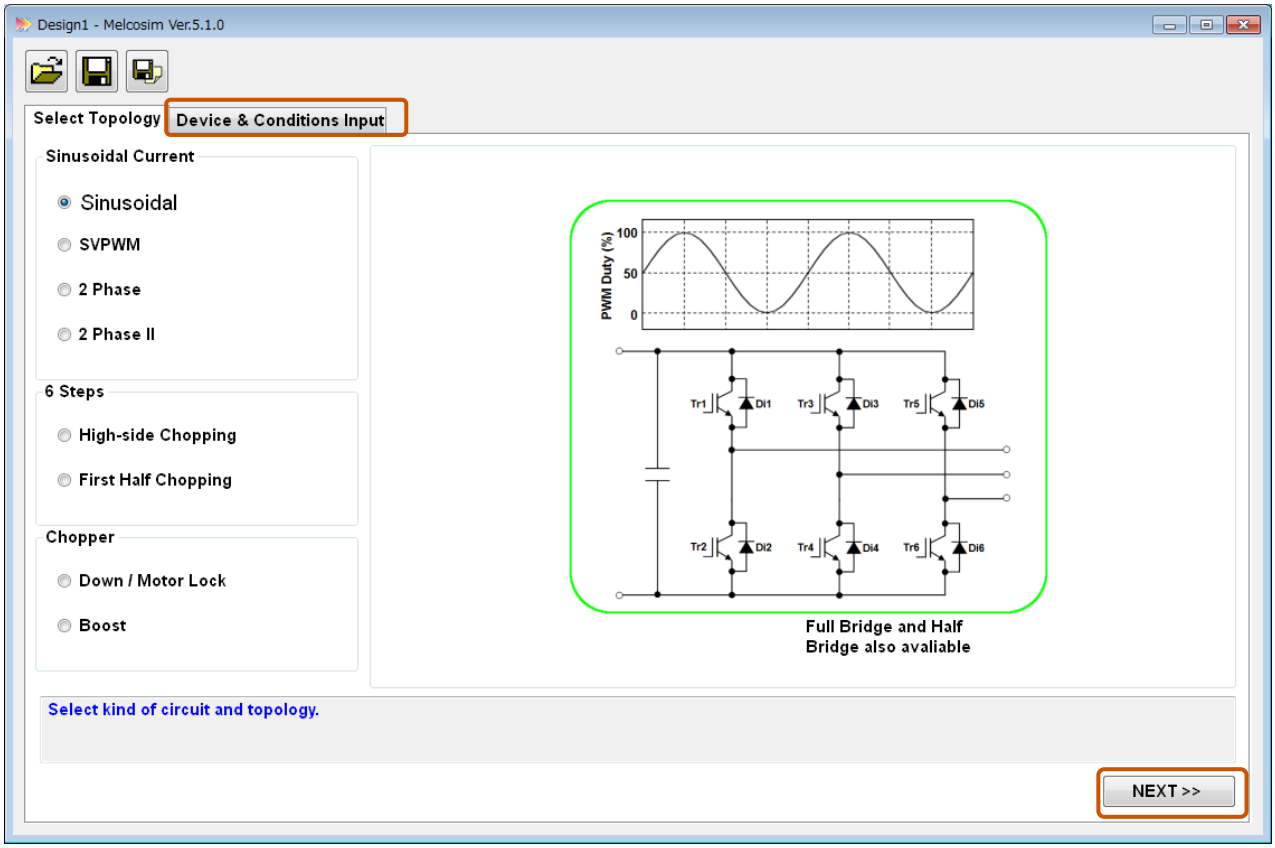
## 3.2 New design calculation

### 3.2.1 Main window

Click the [2 Level New Design] button.

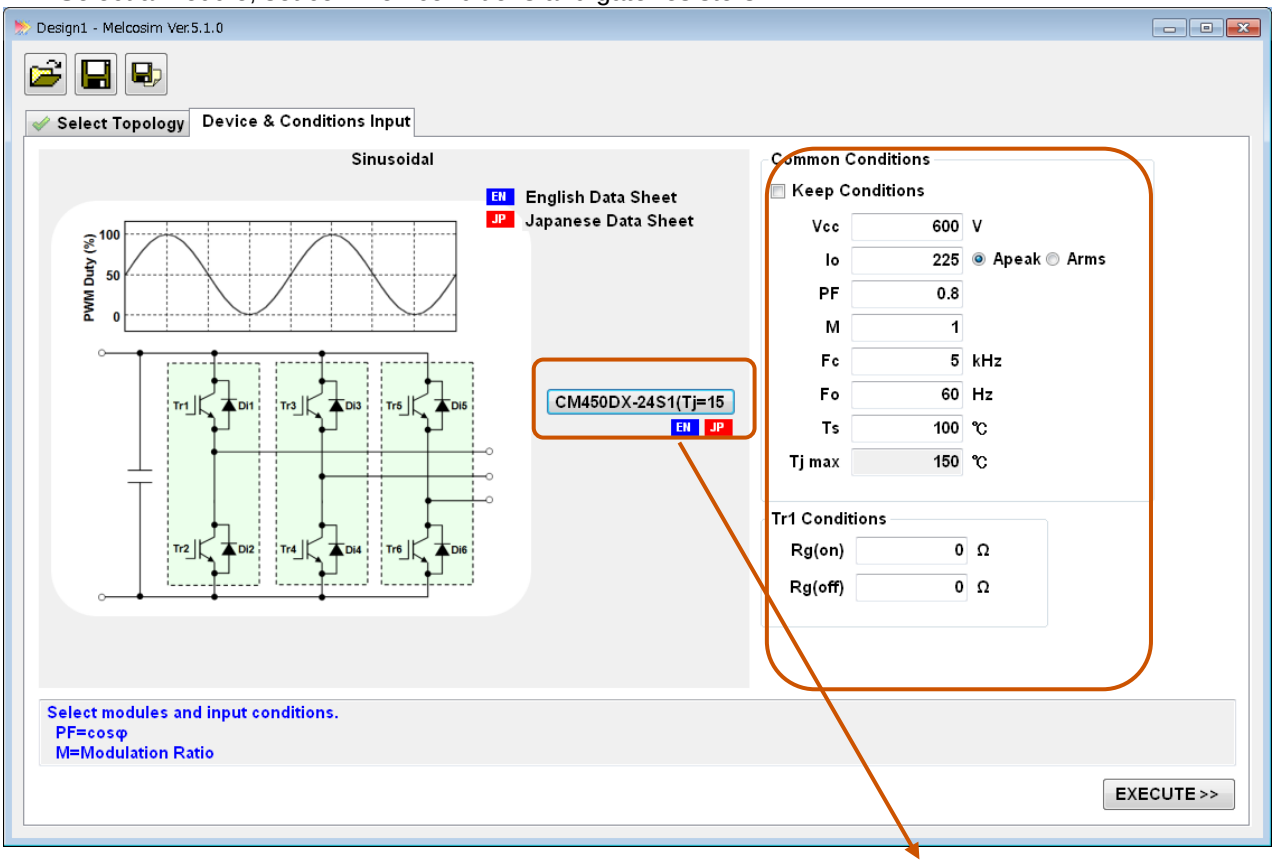

### 3.2.2 Select Topology Window

Click the button for the selection of "Sinusoidal" and click the [NEXT>>] button or the [Device & Conditions Input] tab.

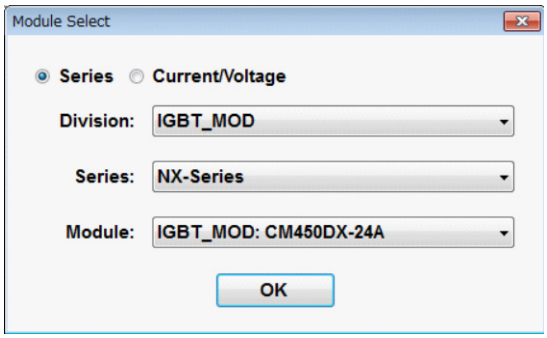


### 3.2.3 Device & conditions input window

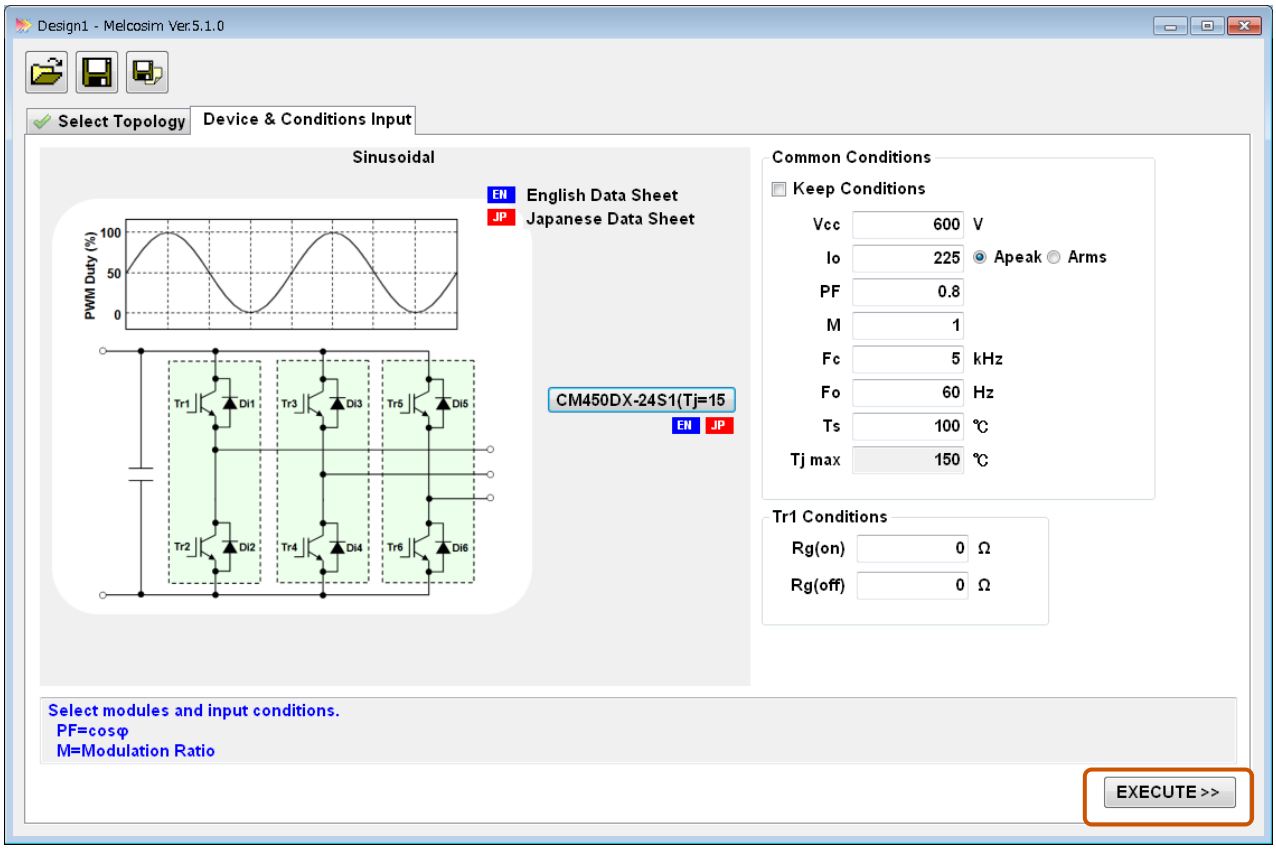
Select a module, set common conditions and gate resistors.




Common Conditions are set automatically to default conditions when a power module has been selected.

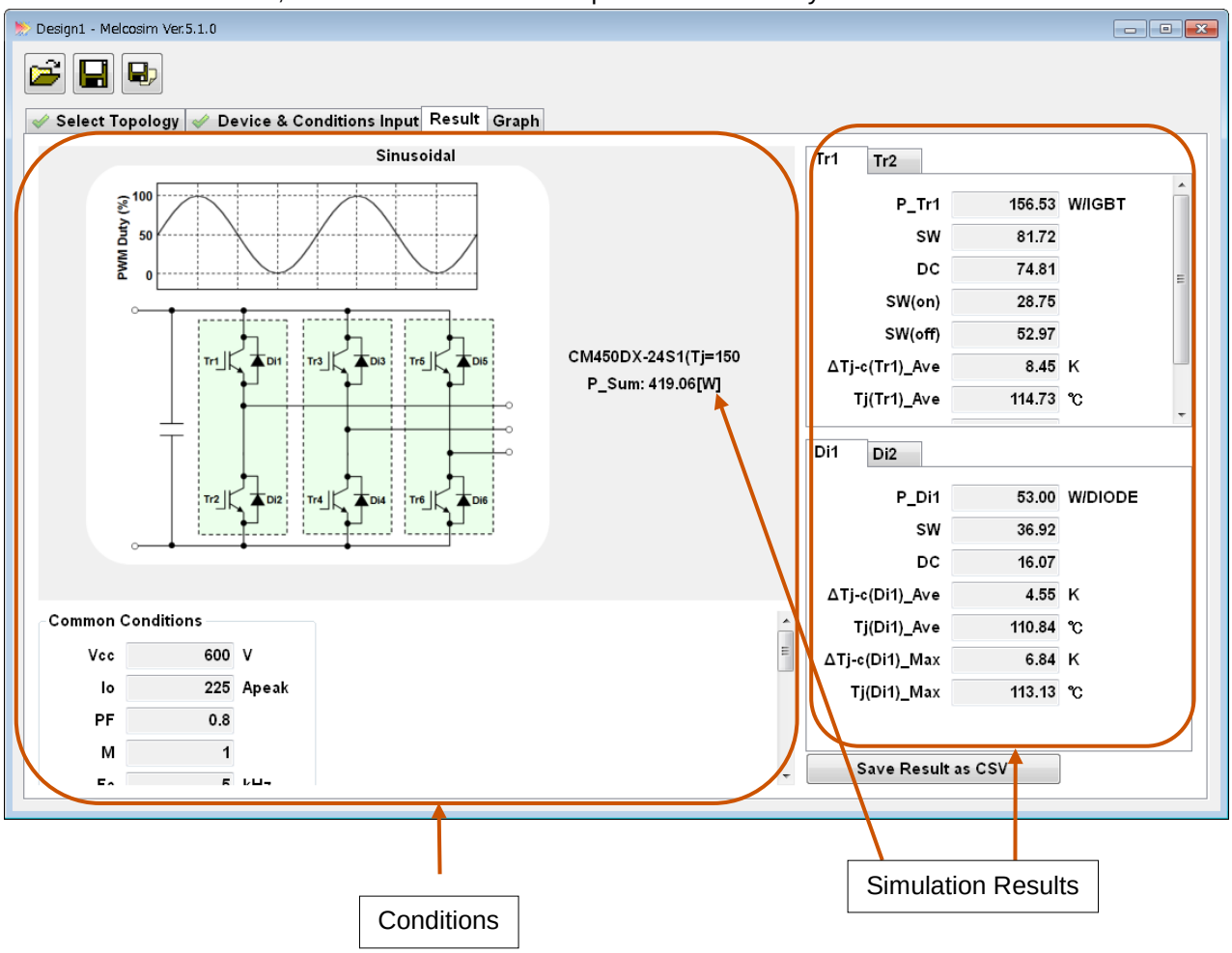



After selection of all devices and setting conditions, click the [EXECUTE>>] button.
NOTE) In case a device or data has not been input into the conditions, the [EXECUTE>>] button is not available.



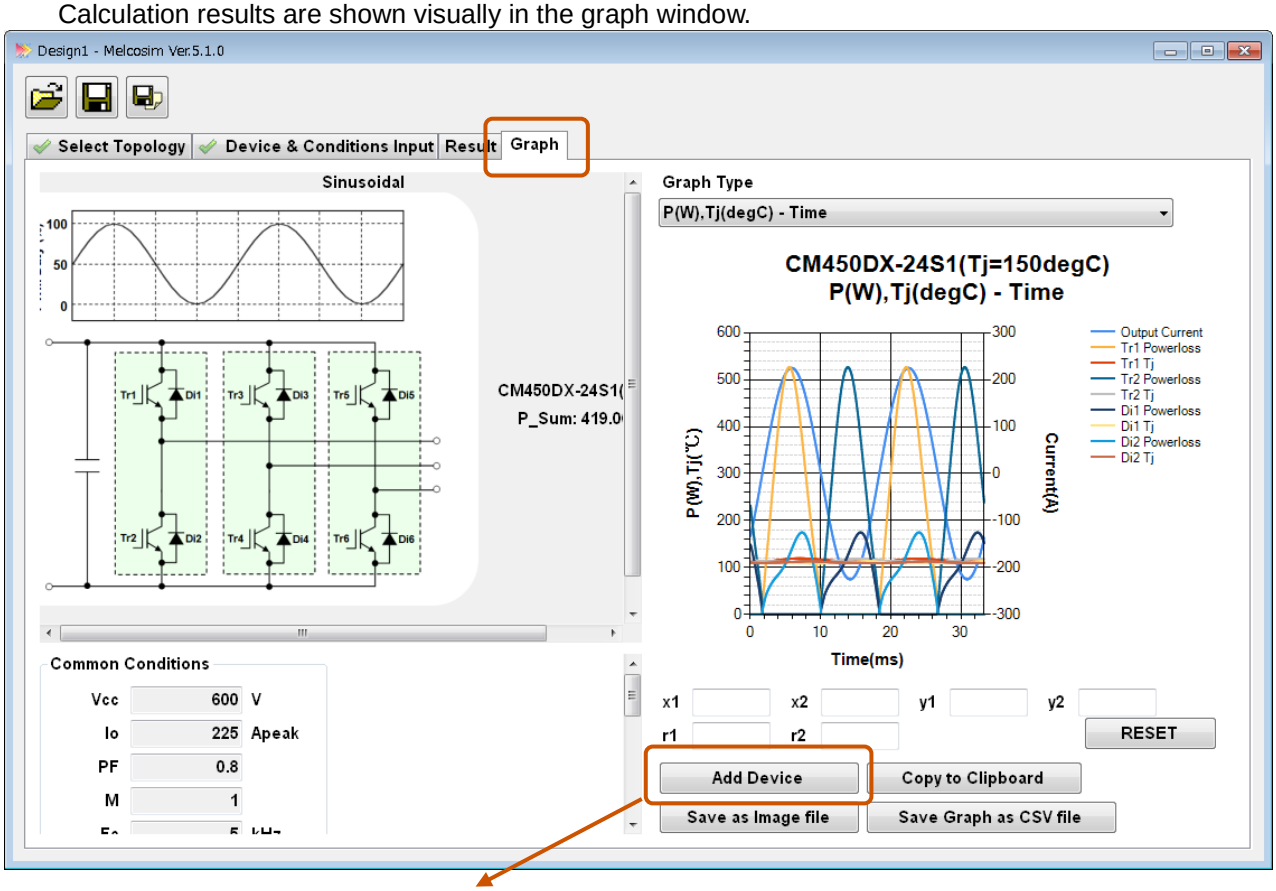

### 3.2.4 Result window

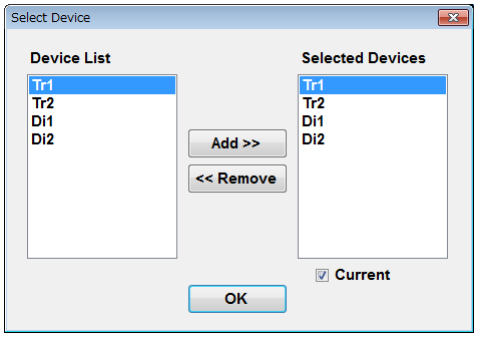
A few seconds later, the result window will be opened automatically with calculation results.



### 3.2.5 Graph window

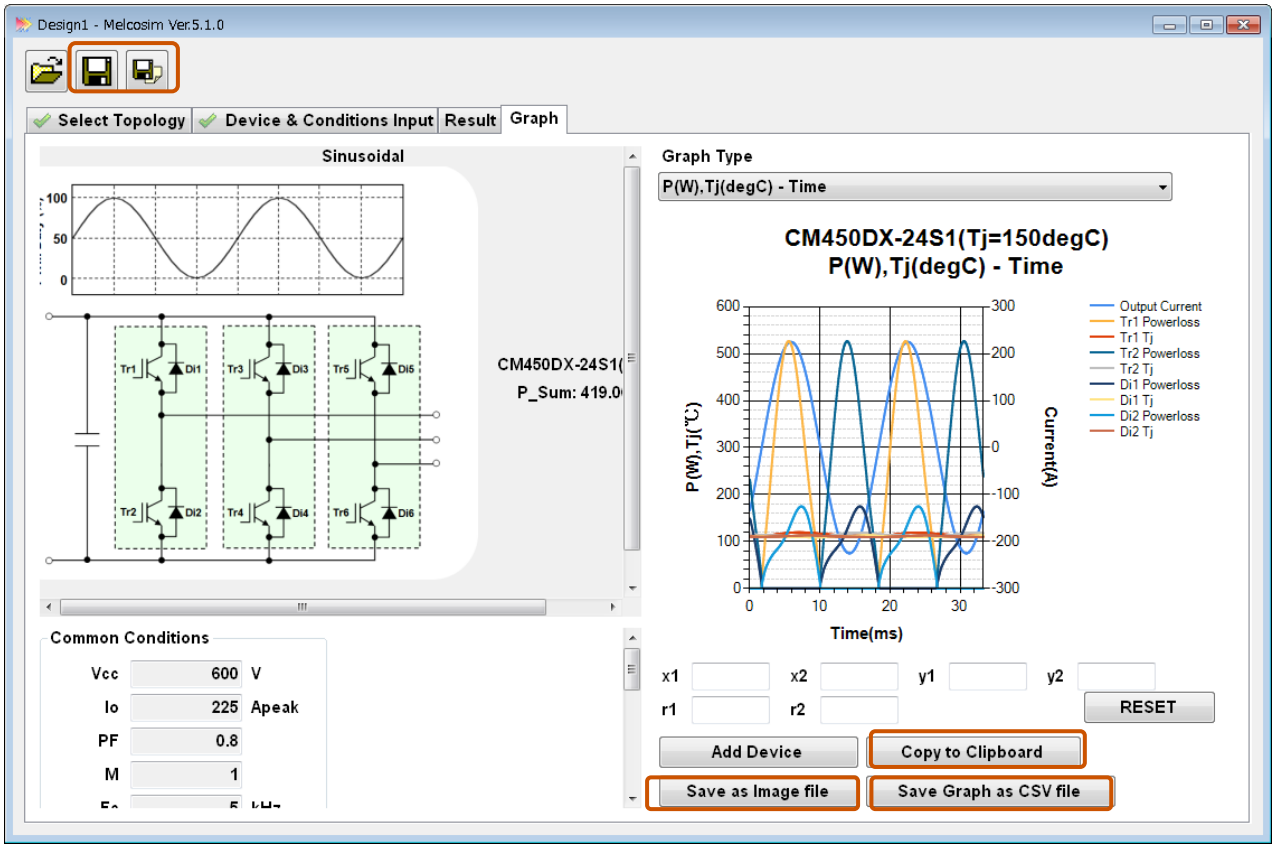
Calculation results are shown visually in the graph window.



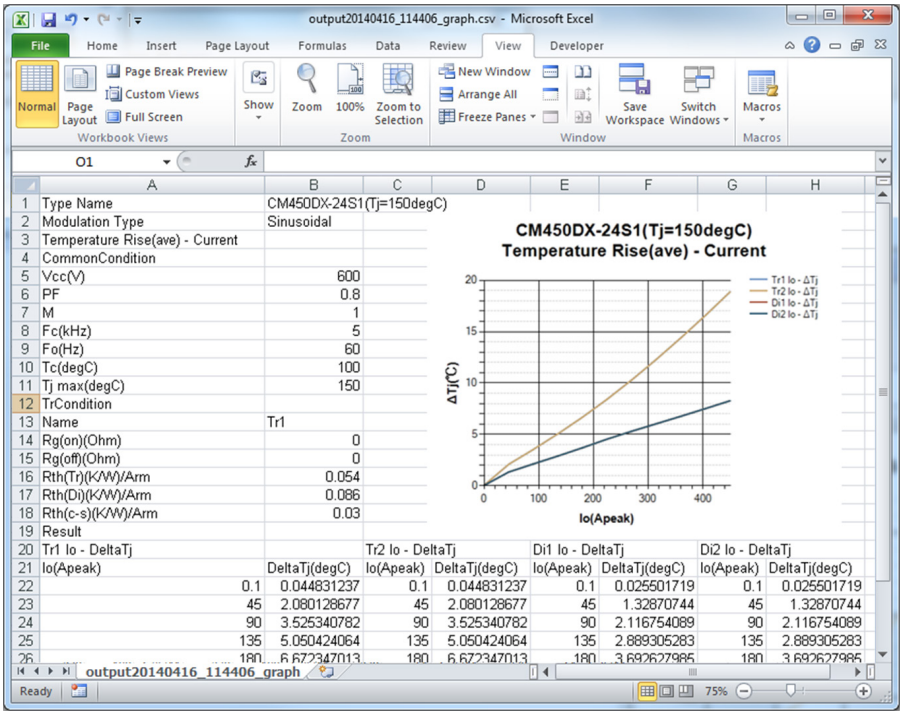

Adding or removing elements of the device is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at upper left side of the screen.




Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save as Image file]

For example: It is possible to open the CSV file of text data and then paste PNG data of graph.




Maximize window and expand graph width is recommended for getting better graph resolution.

## 3.3 Opening previous designs

### 3.3.1 Open the last saved design

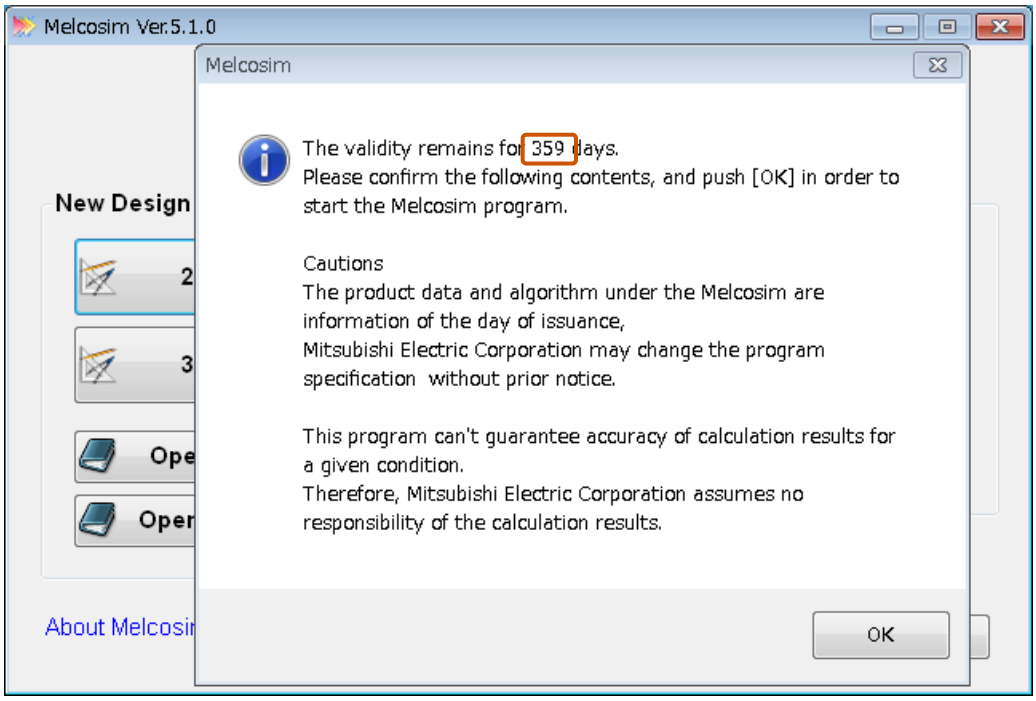

In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

### 3.3.2 Open the saved design in folders

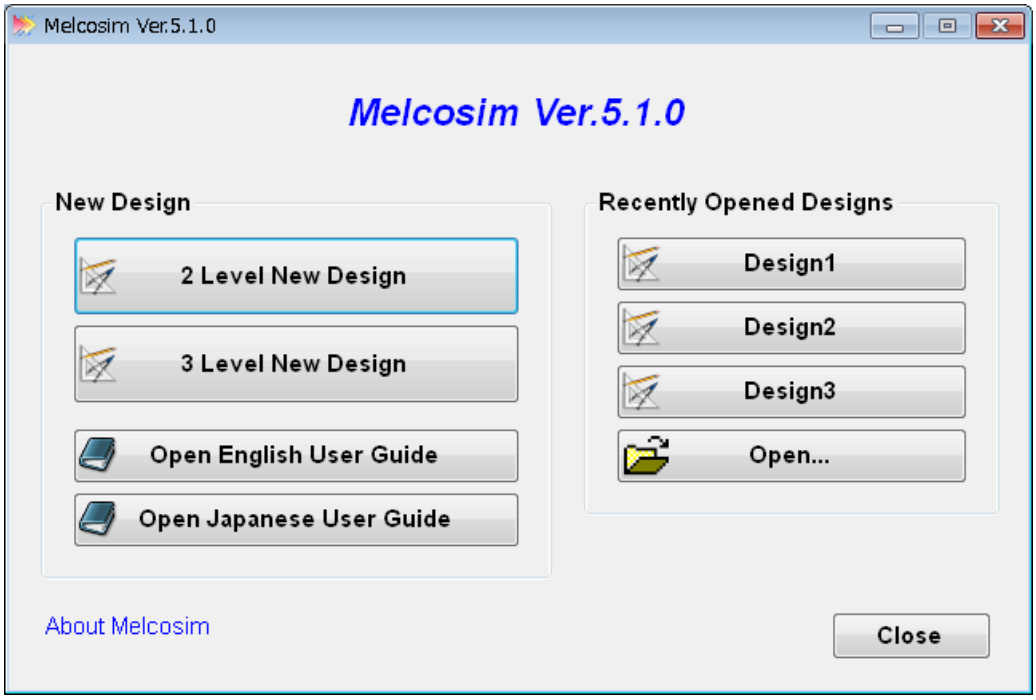
# 4 Loss calculation in chopper (Down/Motor Lock, Boost) configuration

## 4.1 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.




Click OK, then move to the main window in the case that the expiration date is still valid.



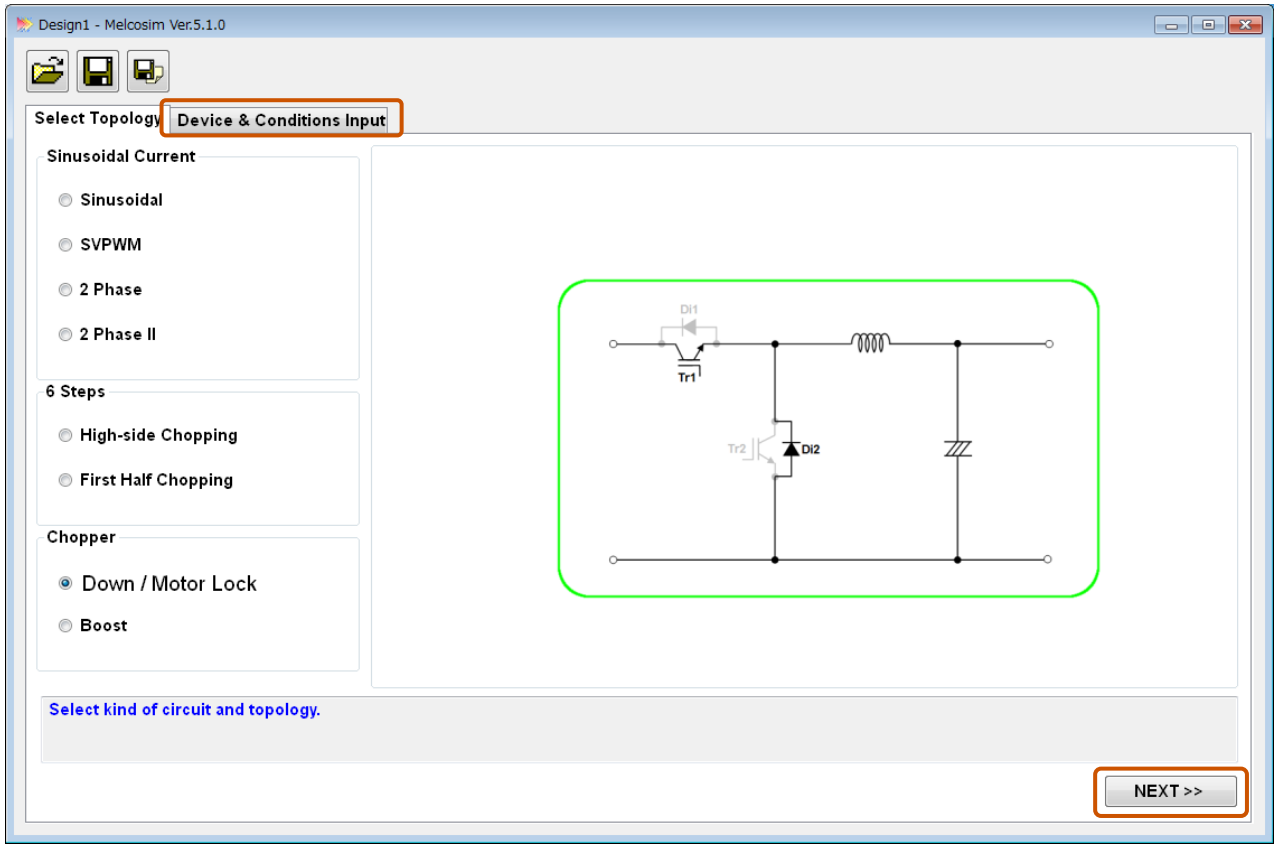
## 4.2 New design calculation

### 4.2.1 Main window

Click the [2 Level New Design] button.

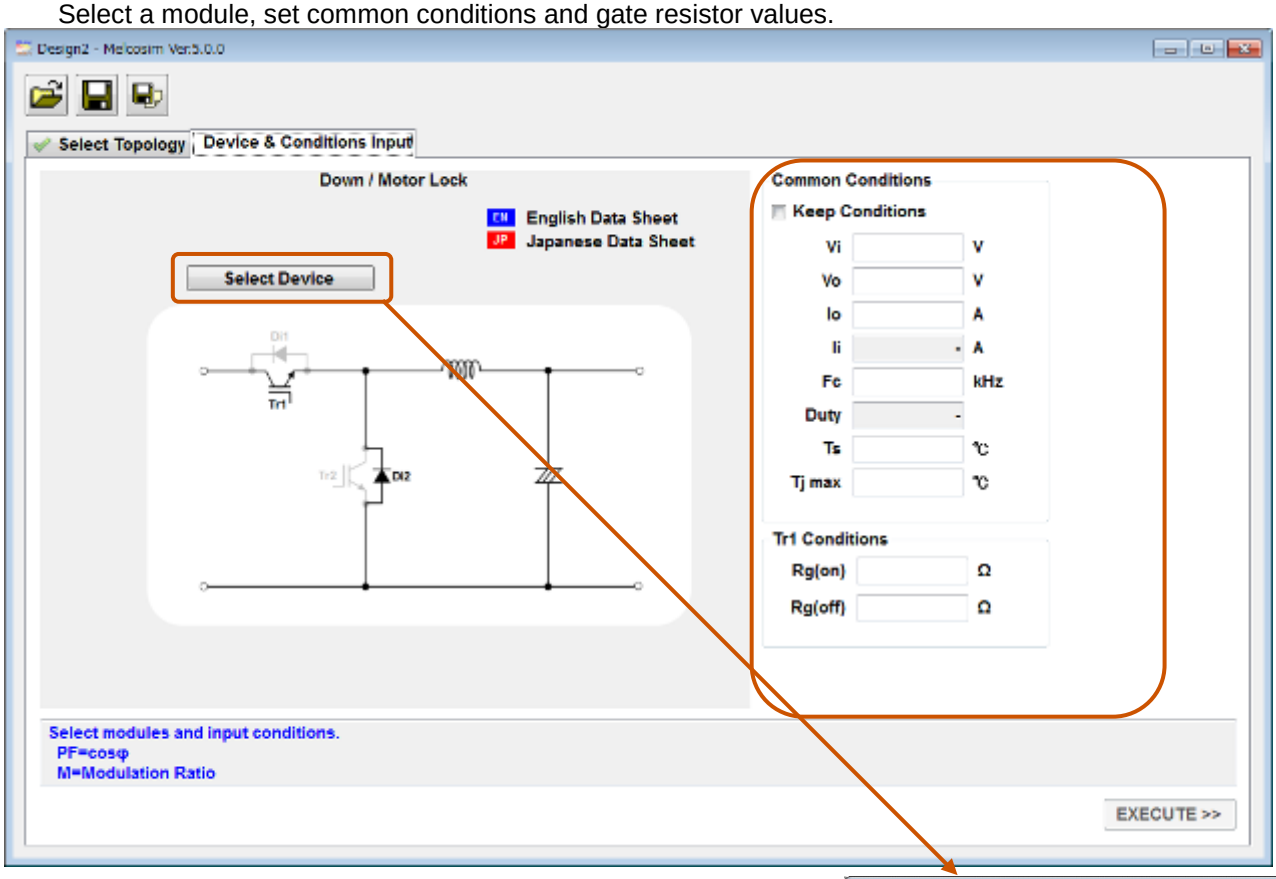

### 4.2.2 Select topology window

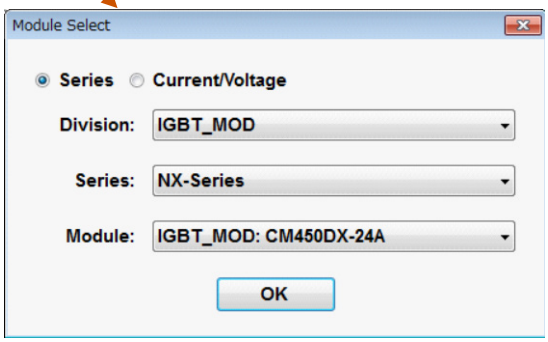
Click the button for the selection of "Sinusoidal" and click the [NEXT>>] button or the [Device & Conditions Input] tab.



### 4.2.3 Device & conditions input window

Select a module, set common conditions and gate resistor values.

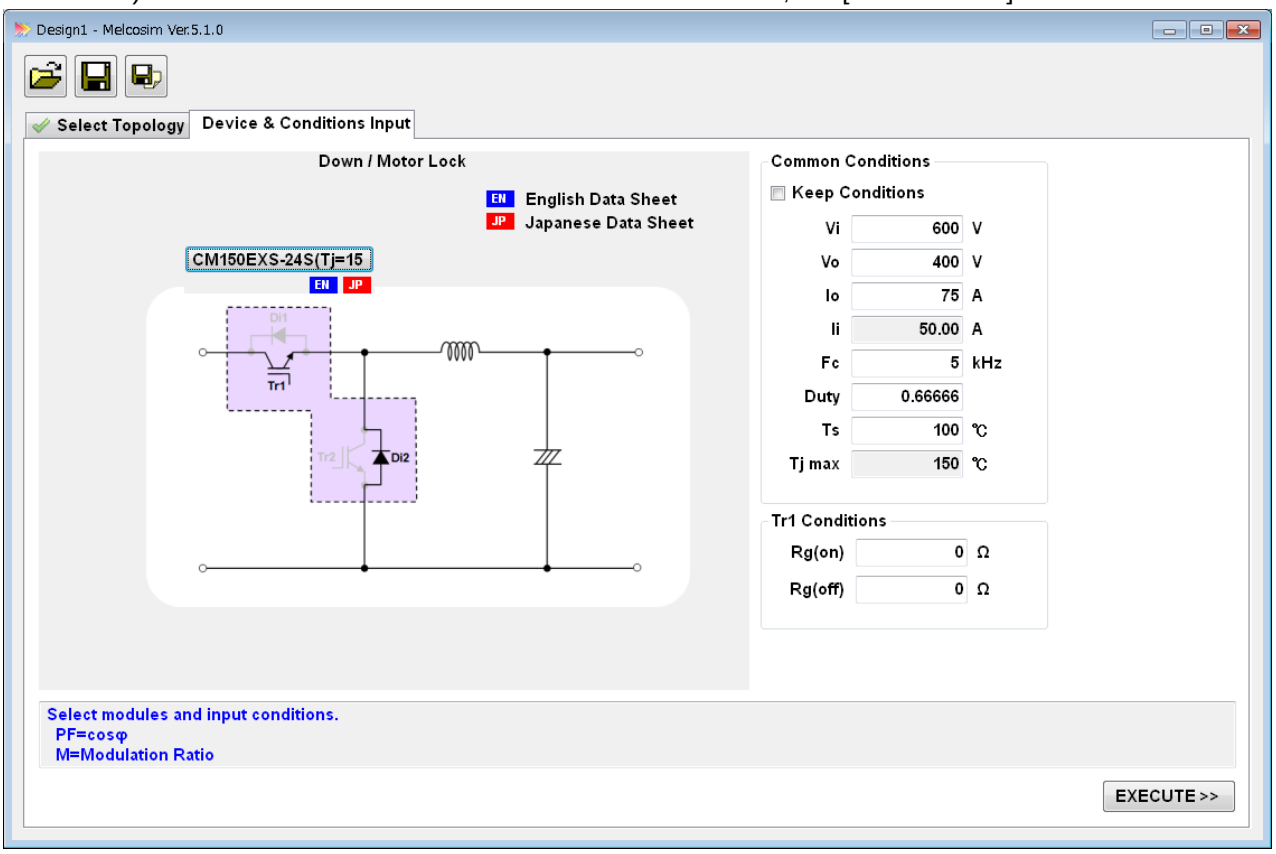


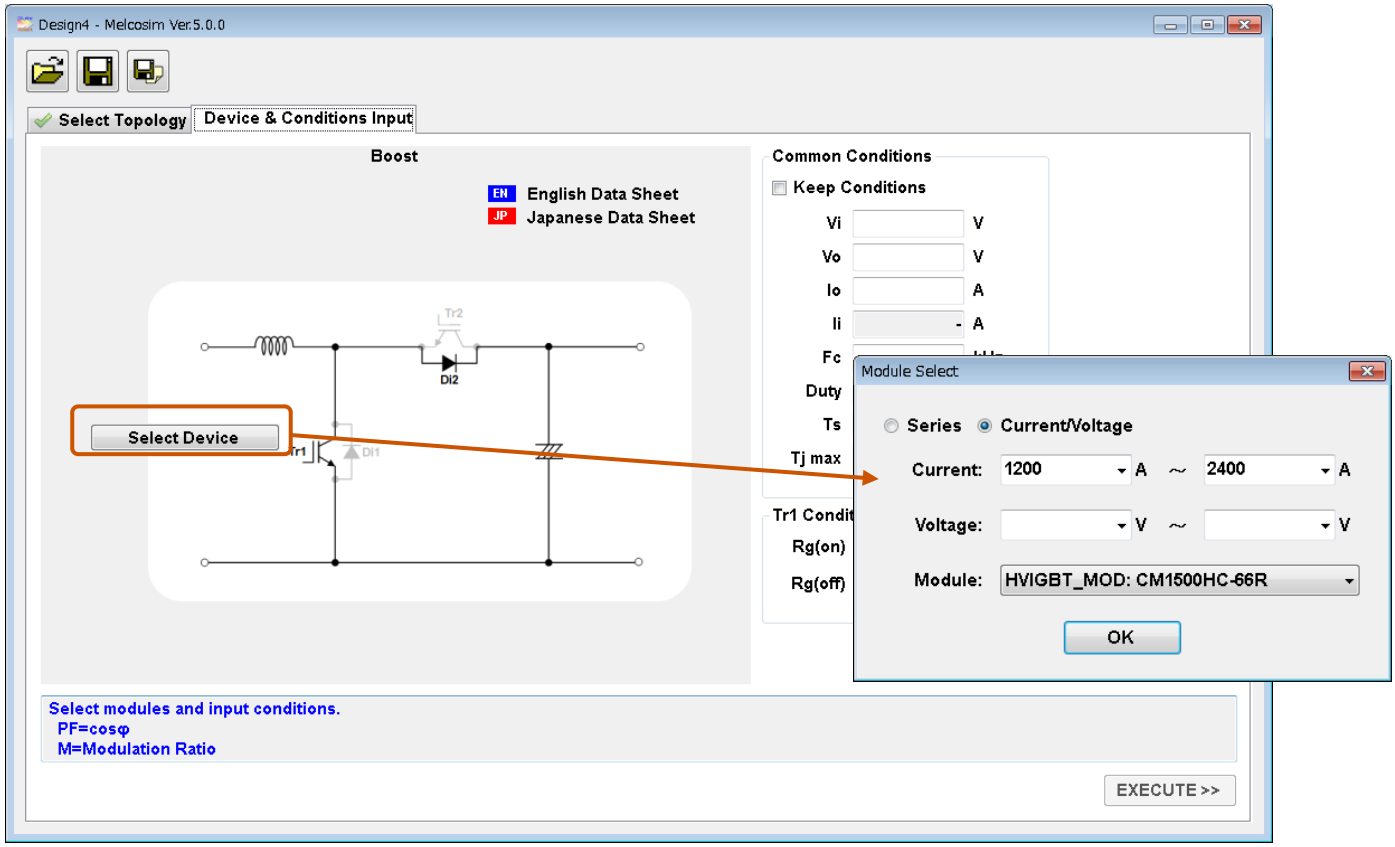




Common conditions are set automatically to default conditions when a power module has been selected.

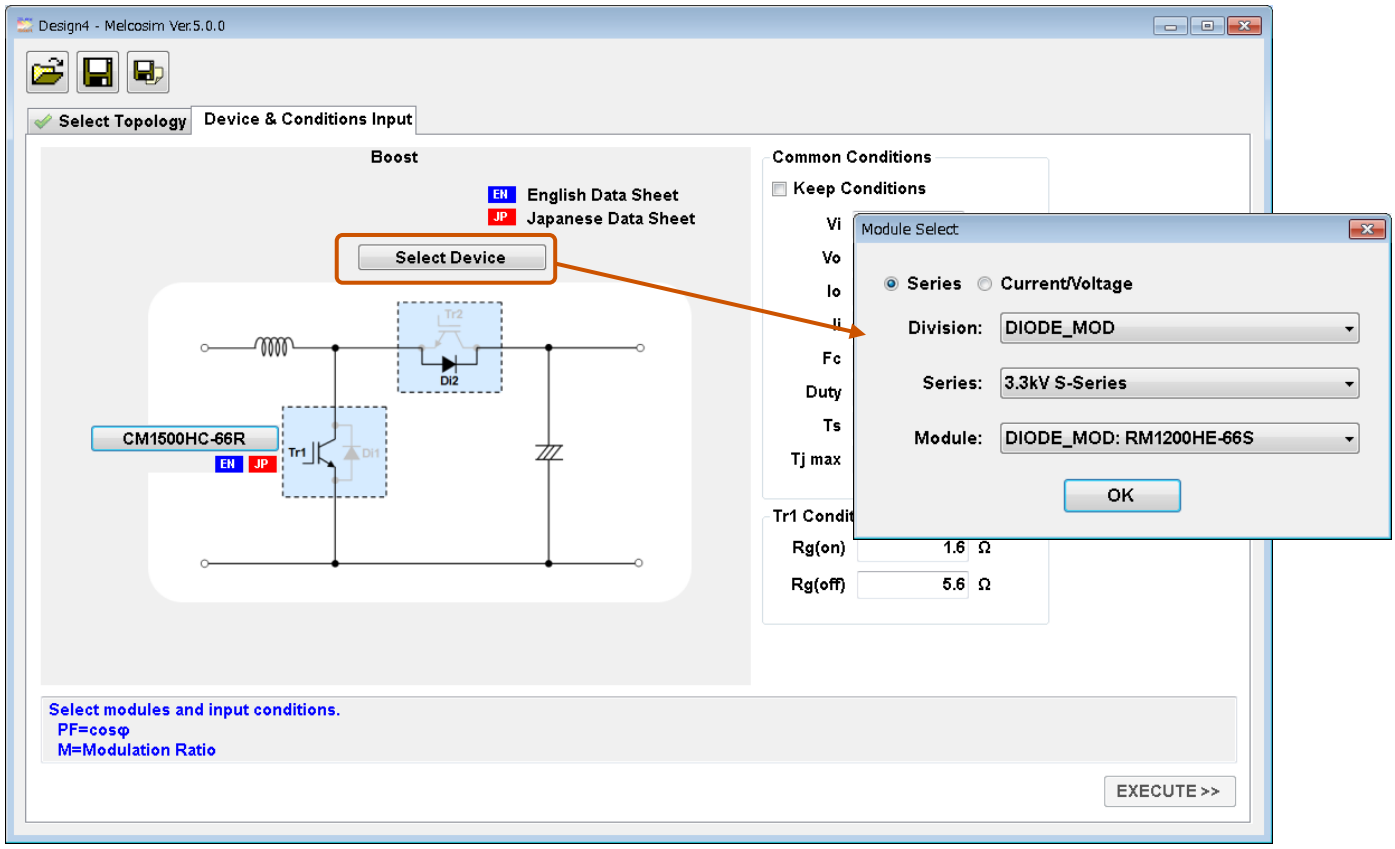
After selecting all devices and set conditions, click the [EXECUTE>>] button.
The duty is calculated from the input voltage Vi and the output voltage Vo.
The Input current Ii is calculated automatically from Io and the duty respectively.

NOTE) In case of no-selection device or no data in conditions, the [EXECUTE>>] button is not available.



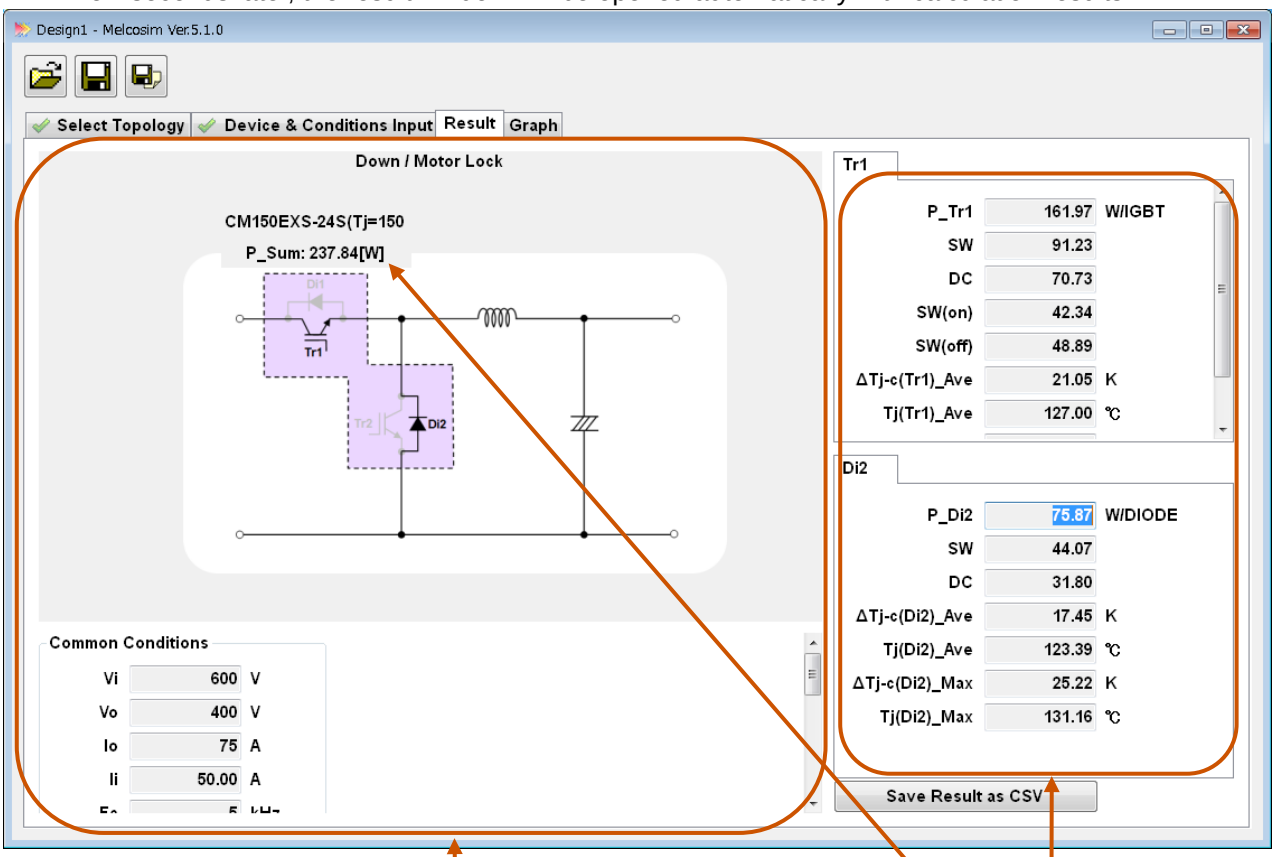



Show up the [Select Device] button for FRDi in case on selecting 1in1module for Transistor.



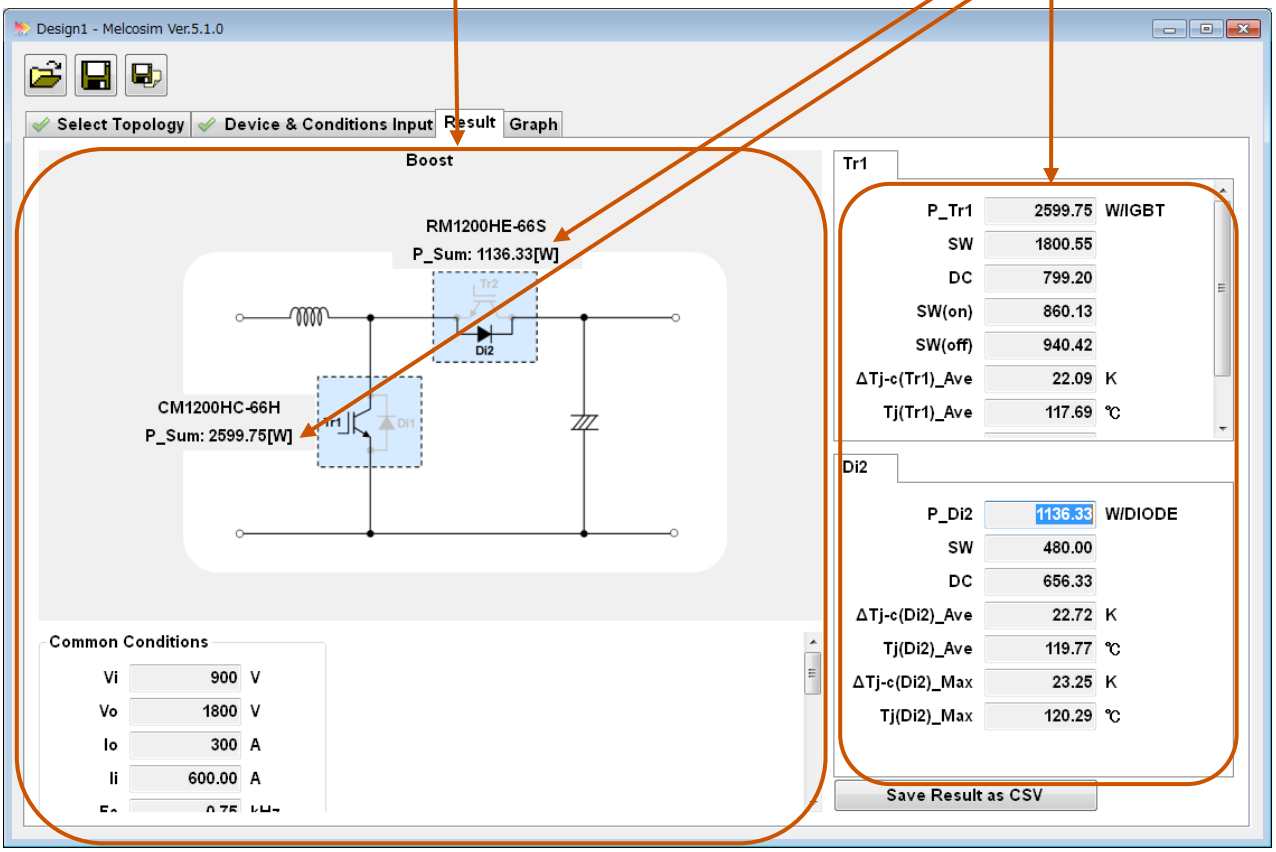
### 4.2.4 Result window

A few seconds later, the result window will be opened automatically with calculation results.



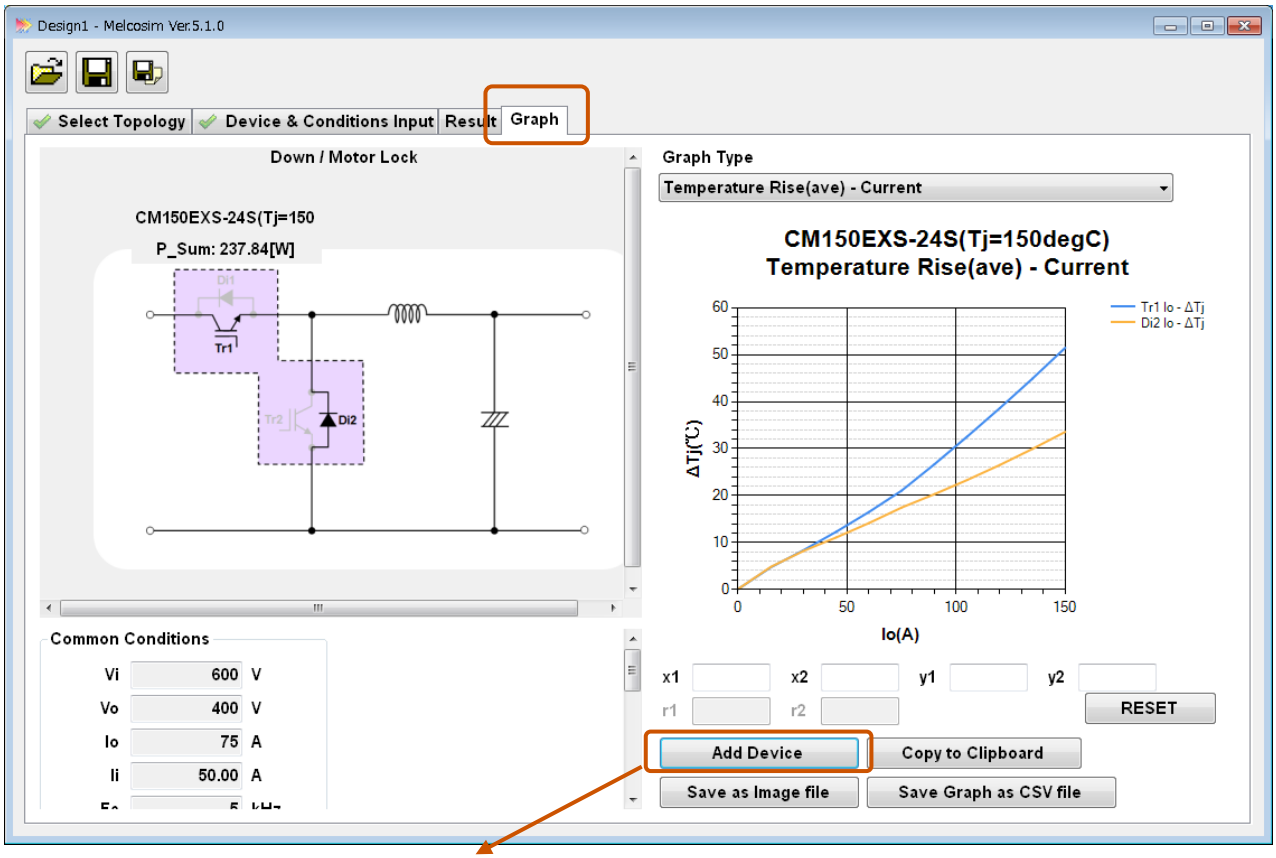

Conditions

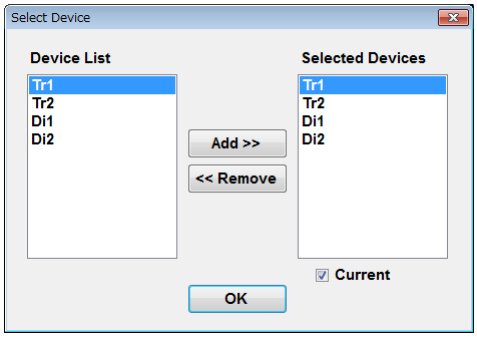
Simulation Results



### 4.2.5 Graph window

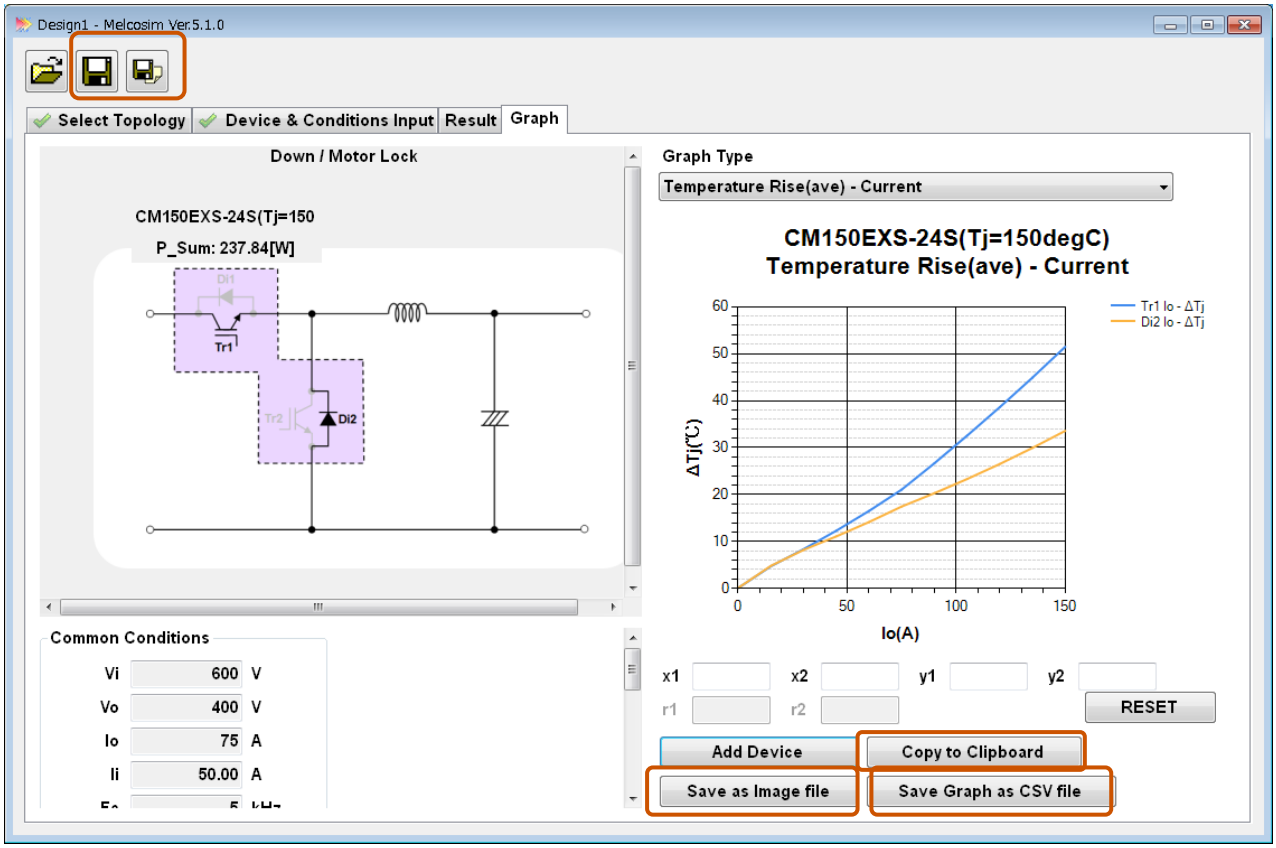
Calculation results are shown visually in the graph window.



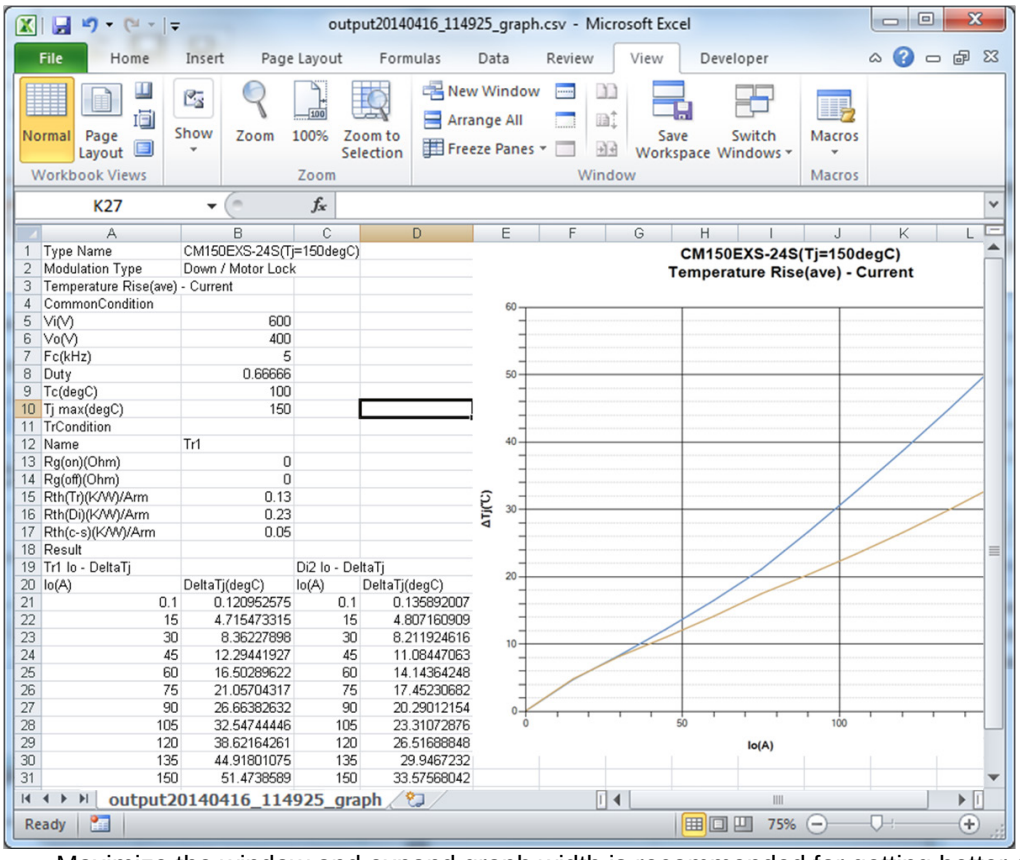




Adding or removing elements of the device is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at upper left side of the screen.




Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save as Image file]
For example: It is possible to open the CSV file of text data and then paste PNG data of graph into that file.




| | A | B | C | D |
|---|---|---|---|---|
| 1 | Type Name | CM150EXS-24S(Tj=150degC) | | |
| 2 | Modulation Type | Down / Motor Lock | | |
| 3 | Temperature Rise(ave) | - Current | | |
| 4 | CommonCondition | | | |
| 5 | Vi(V) | 600 | | |
| 6 | Vo(V) | 400 | | |
| 7 | Fc(kHz) | 5 | | |
| 8 | Duty | 0.66666 | | |
| 9 | Tc(degC) | 100 | | |
| 10 | Tj max(degC) | 150 | | |
| 11 | TrCondition | | | |
| 12 | Name | Tr1 | | |
| 13 | Rg(on)(Ohm) | 0 | | |
| 14 | Rg(off)(Ohm) | 0 | | |
| 15 | Rth(Tr)(K/W)/Arm | 0.13 | | |
| 16 | Rth(Di)(K/W)/Arm | 0.23 | | |
| 17 | Rth(c-s)(K/W)/Arm | 0.05 | | |
| 18 | Result | | | |
| 19 | Tr1 Io - DeltaTj | | Di2 Io - DeltaTj | |
| 20 | Io(A) | DeltaTj(degC) | Io(A) | DeltaTj(degC) |
| 21 | 0.1 | 0.120952575 | 0.1 | 0.135892007 |
| 22 | 15 | 4.715473315 | 15 | 4.807160909 |
| 23 | 30 | 8.36227898 | 30 | 8.211924616 |
| 24 | 45 | 12.29441927 | 45 | 11.08447063 |
| 25 | 60 | 16.50289622 | 60 | 14.14364248 |
| 26 | 75 | 21.05704317 | 75 | 17.45230682 |
| 27 | 90 | 26.66382632 | 90 | 20.29012154 |
| 28 | 105 | 32.54744446 | 105 | 23.31072876 |
| 29 | 120 | 38.62164261 | 120 | 26.51688848 |
| 30 | 135 | 44.91801075 | 135 | 29.9467232 |
| 31 | 150 | 51.4738589 | 150 | 33.57568042 |

Maximize the window and expand graph width is recommended for getting better graph resolution.

## 4.3 Opening previous designs

### 4.3.1 Open the latest saved design

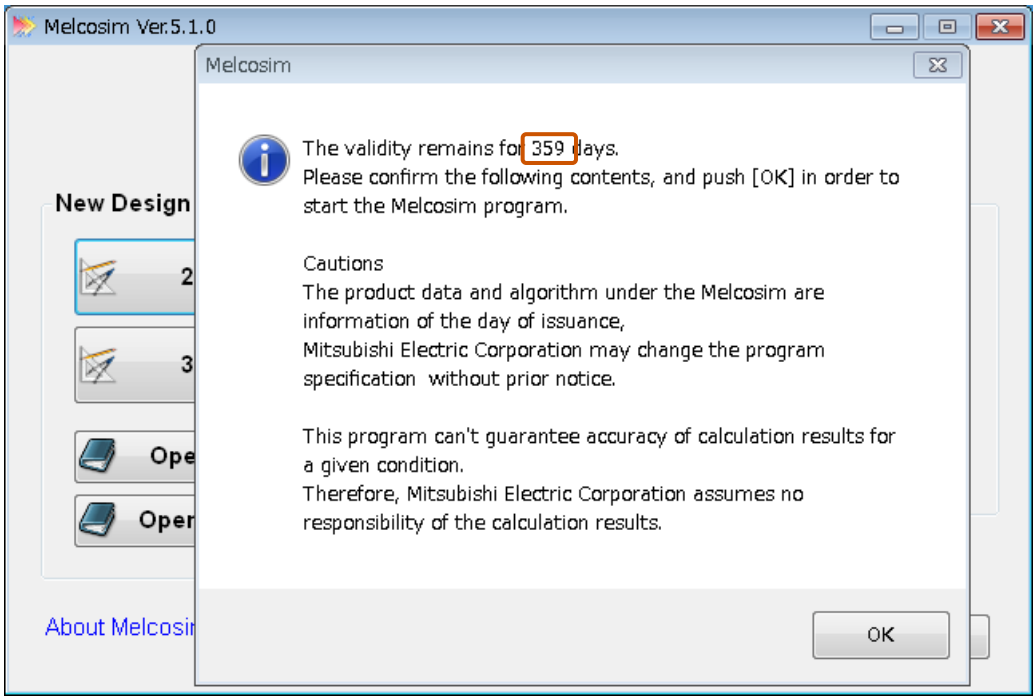

In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

### 4.3.2 Open the saved design in folders

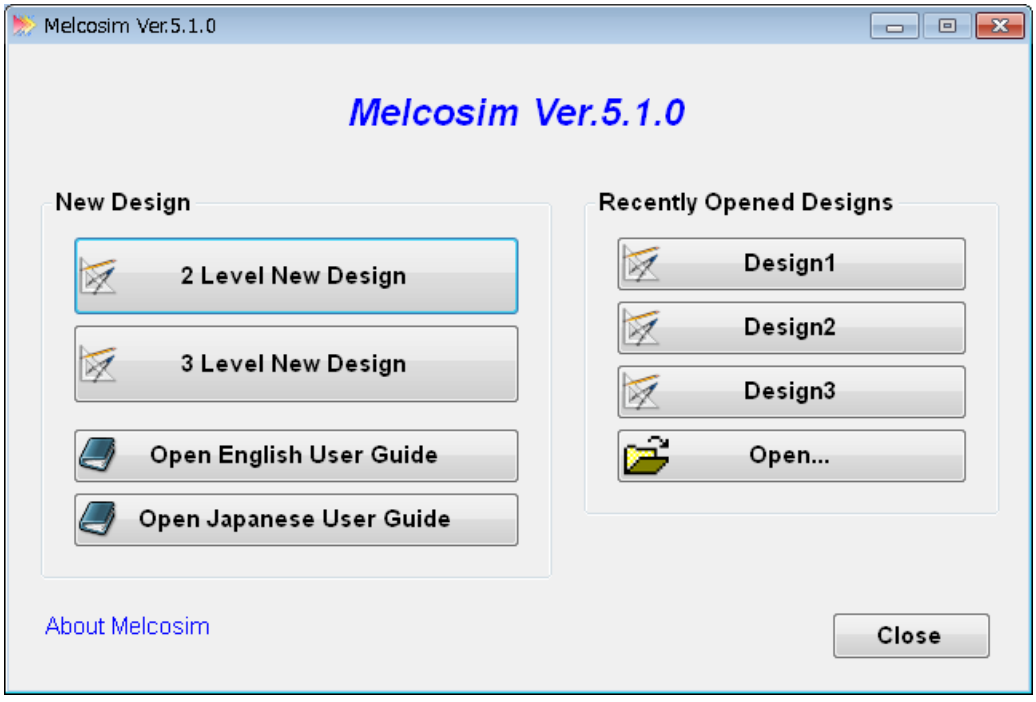
# 5 Loss calculation in I Type NPC configration

## 5.1 Application Start-up

When the software starts up, a message window pops-up showing the validity date of the software.




Click OK, then move to the main window in the case that the expiration date is still valid.



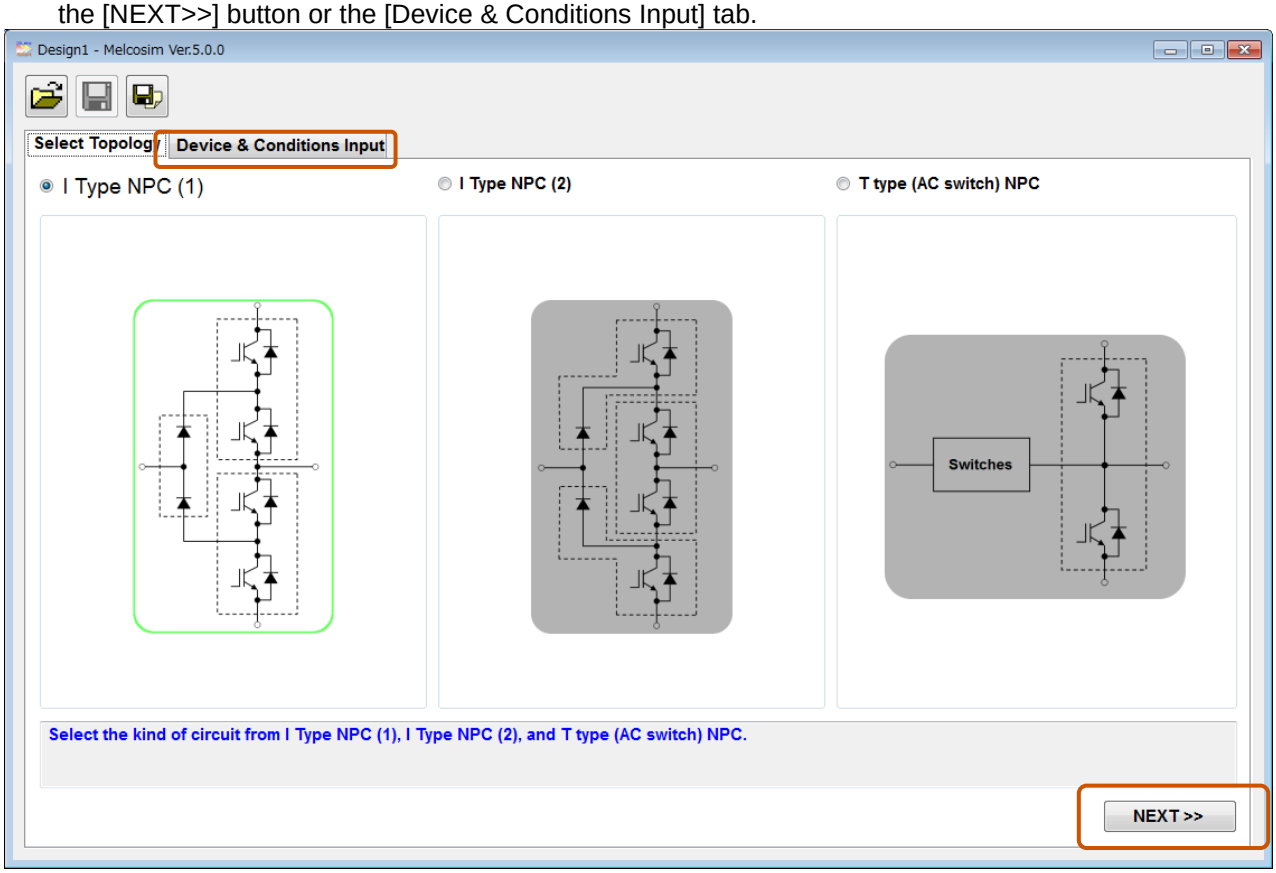
## 5.2 New design calculation

### 5.2.1 Main window

Click the [3Level New Design] button.


### 5.2.2 Select Topology Window

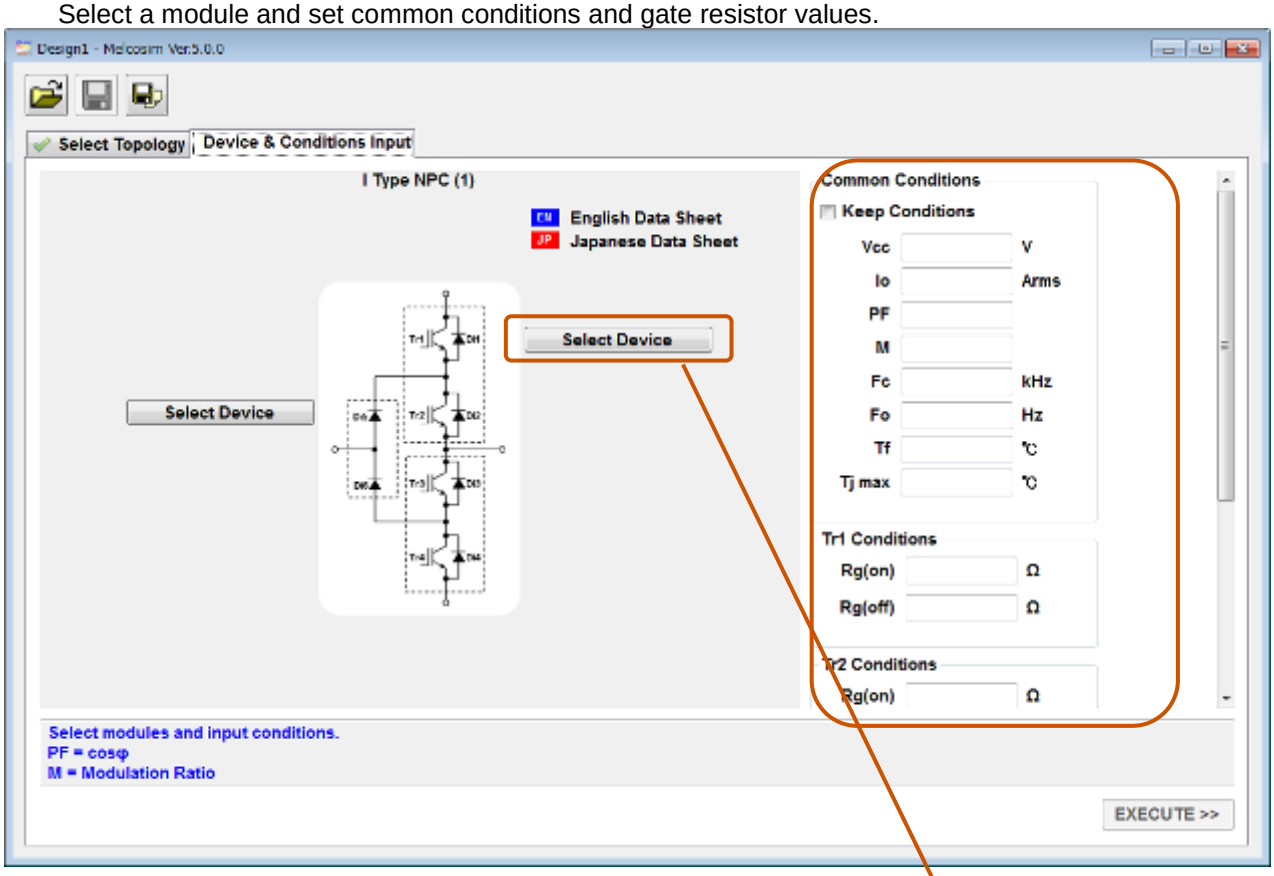
Click on the button or schematic area for the selection of "I Type NPC (1)" or "I Type NPC (2)" and click the [NEXT>>] button or the [Device & Conditions Input] tab.

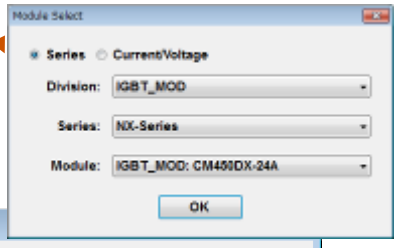



Select " I Type NPC(2)" for applying 2 in1 or chopper module.

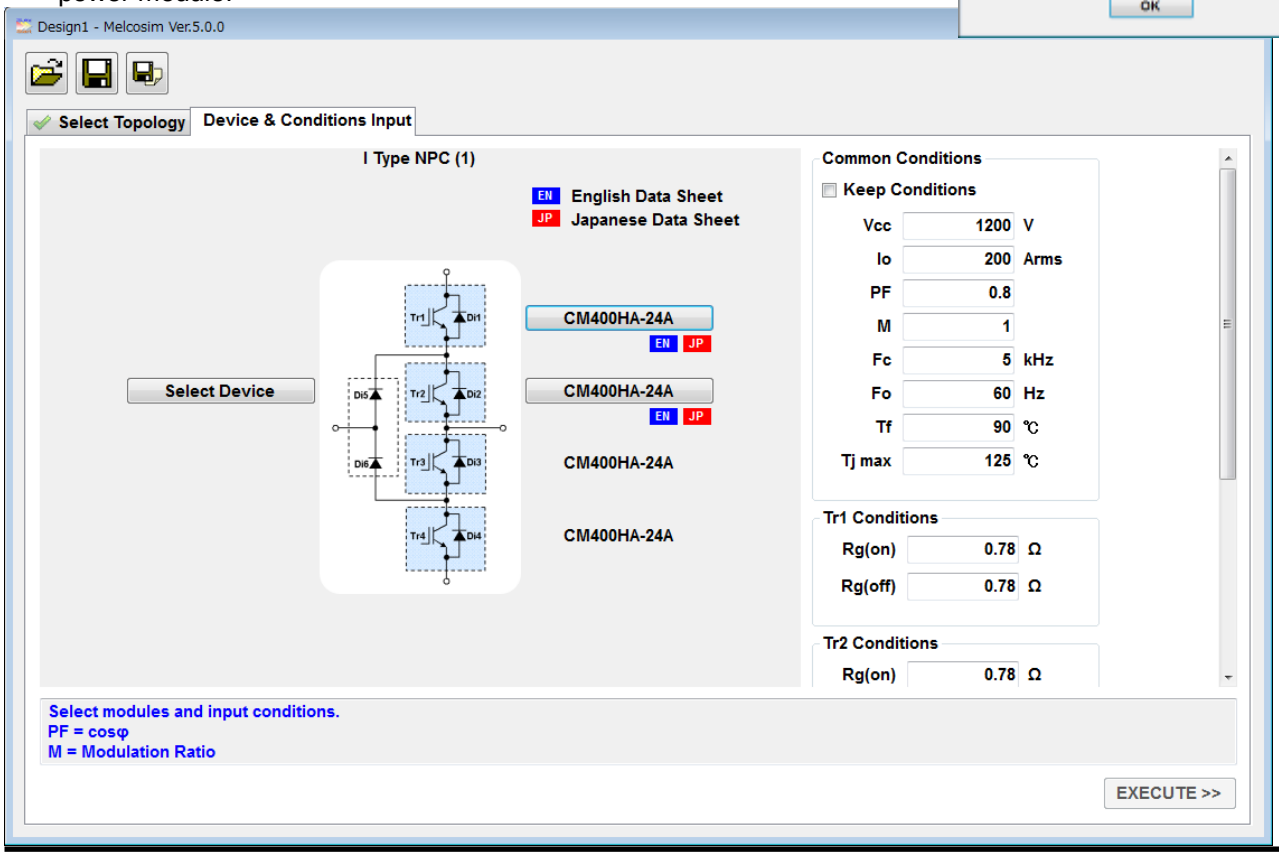
### 5.2.3 Device & conditions input window

Select a module and set common conditions and gate resistor values.

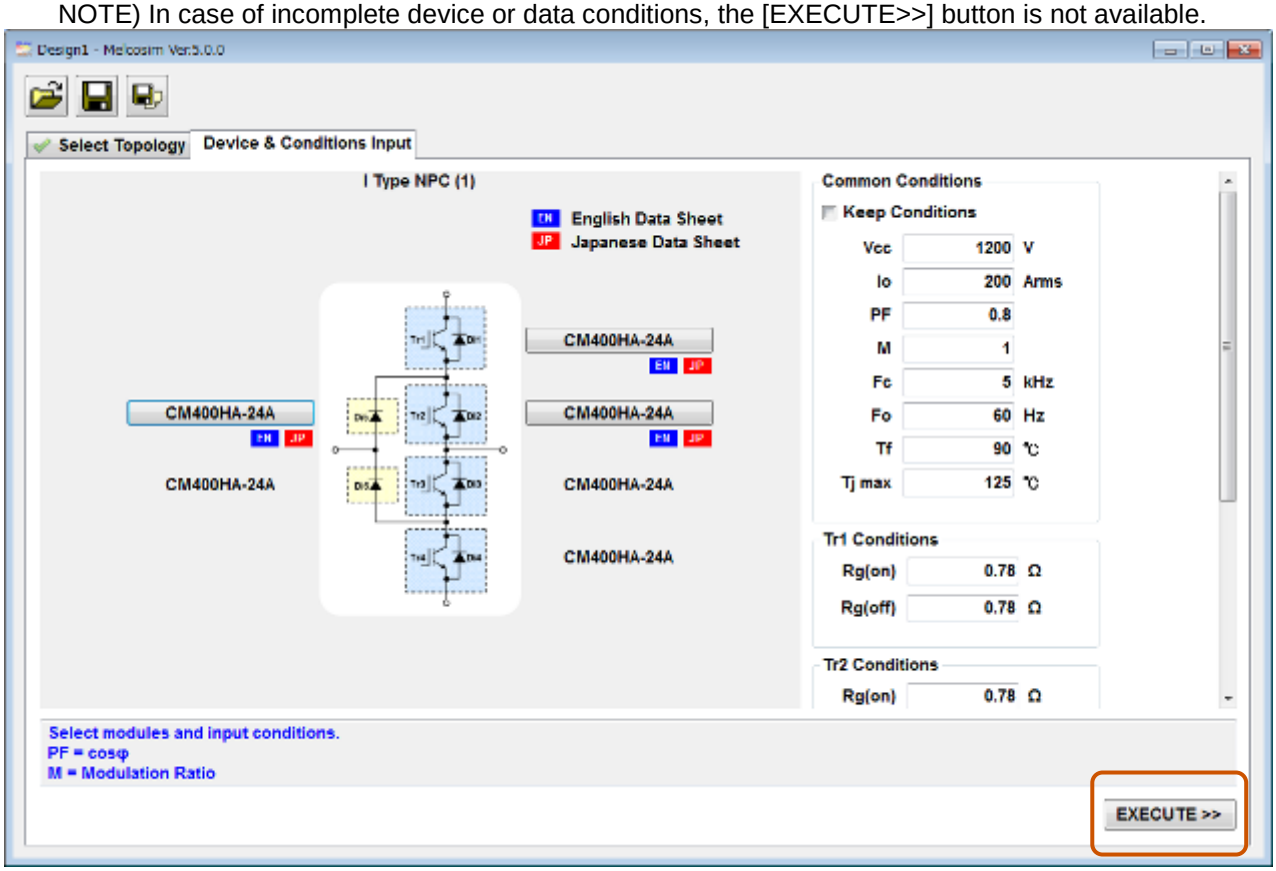



Common Conditions are set automatically when selecting the high side power module.

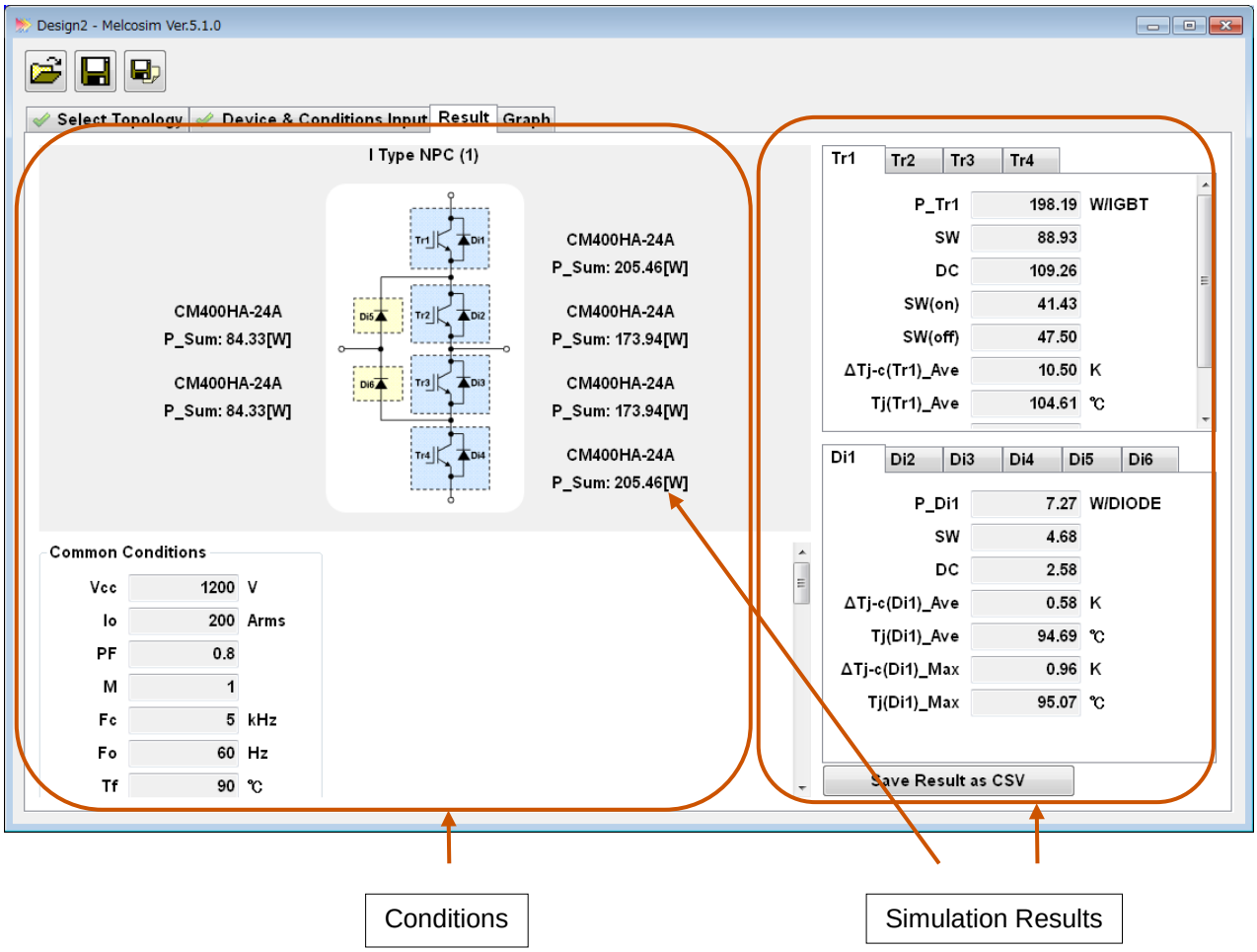


After selecting all devices and having set all conditions, click the [EXECUTE>>] button.
NOTE) In case of incomplete device or data conditions, the [EXECUTE>>] button is not available.



### 5.2.4 Result window

A few seconds later, the result window will be opened automatically with calculation results.

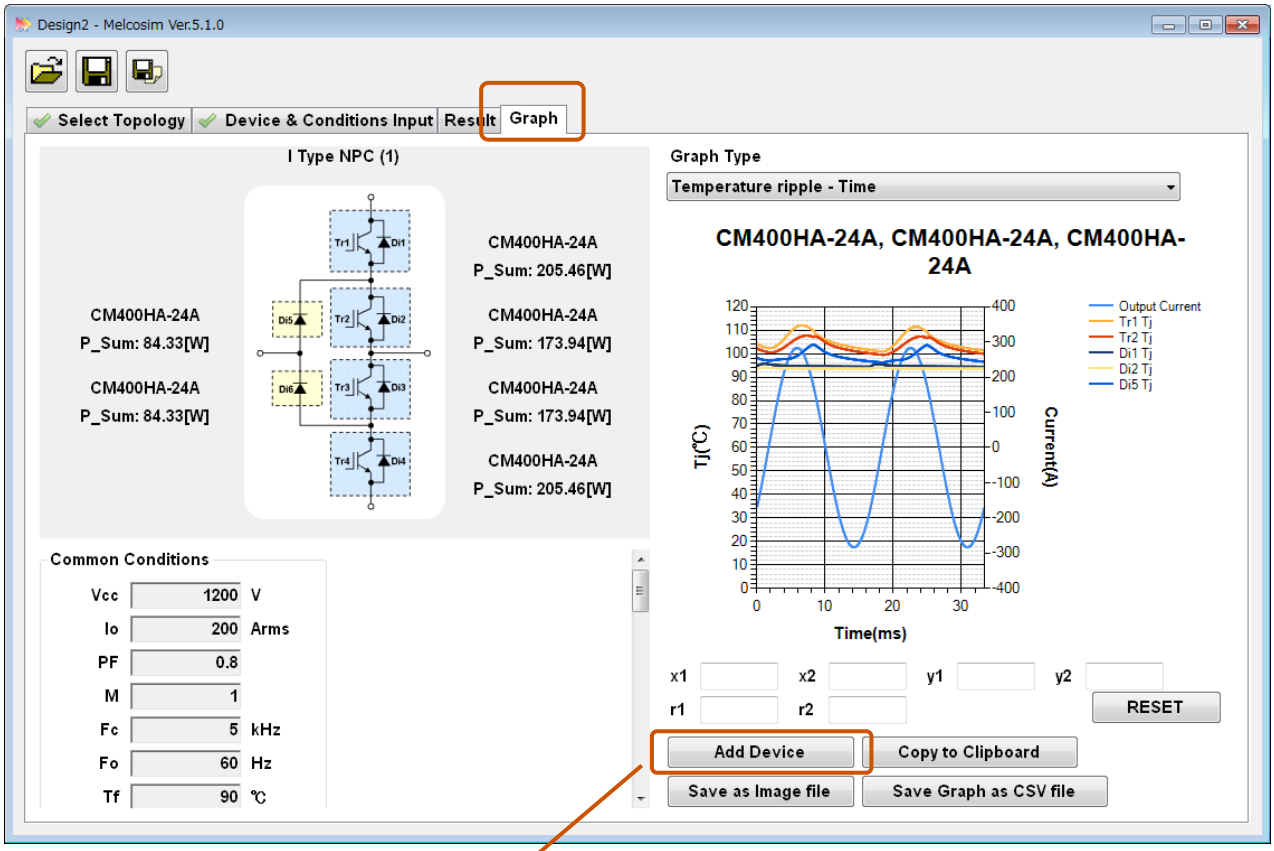


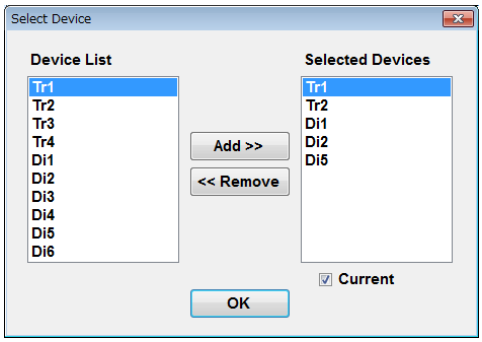

Conditions

Simulation Results

### 5.2.5 Graph window

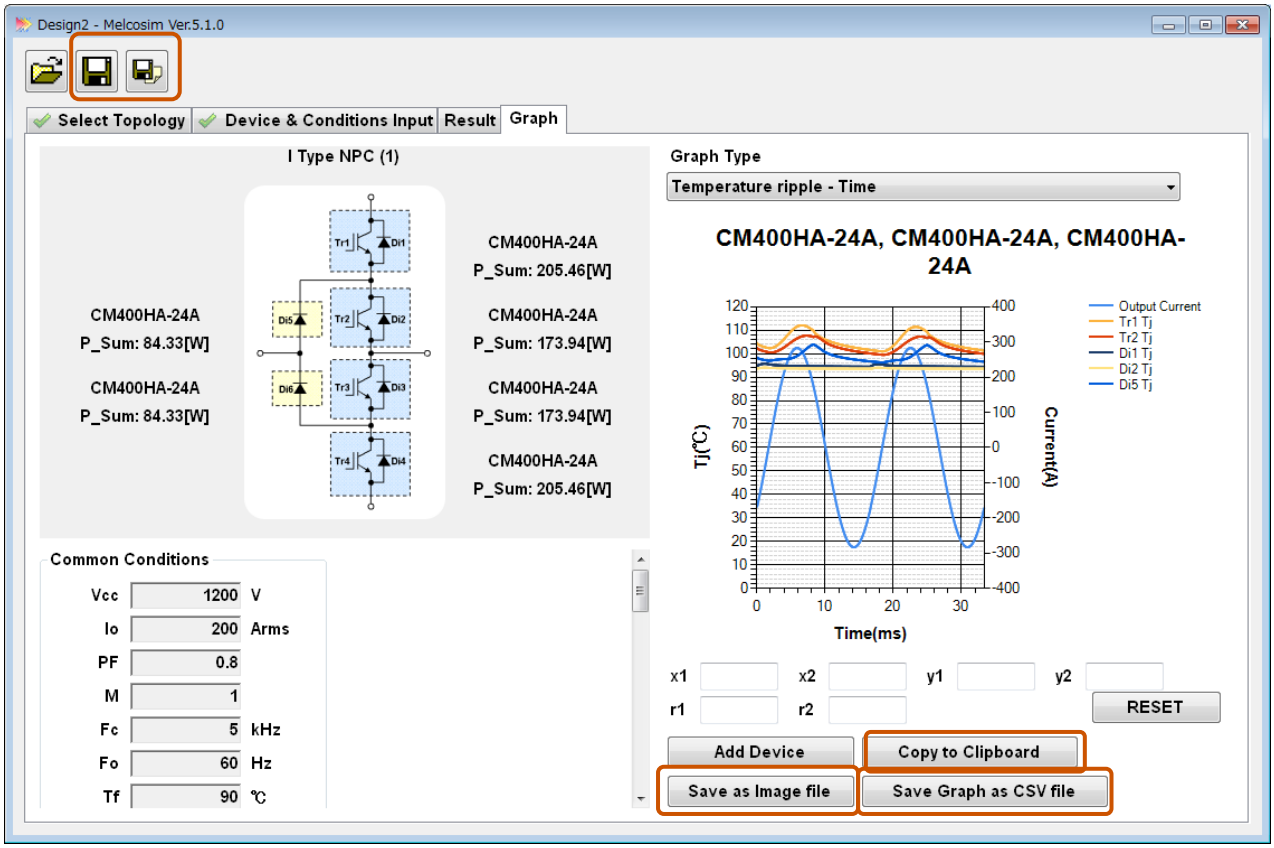
The calculation results are shown visually in the graph window.



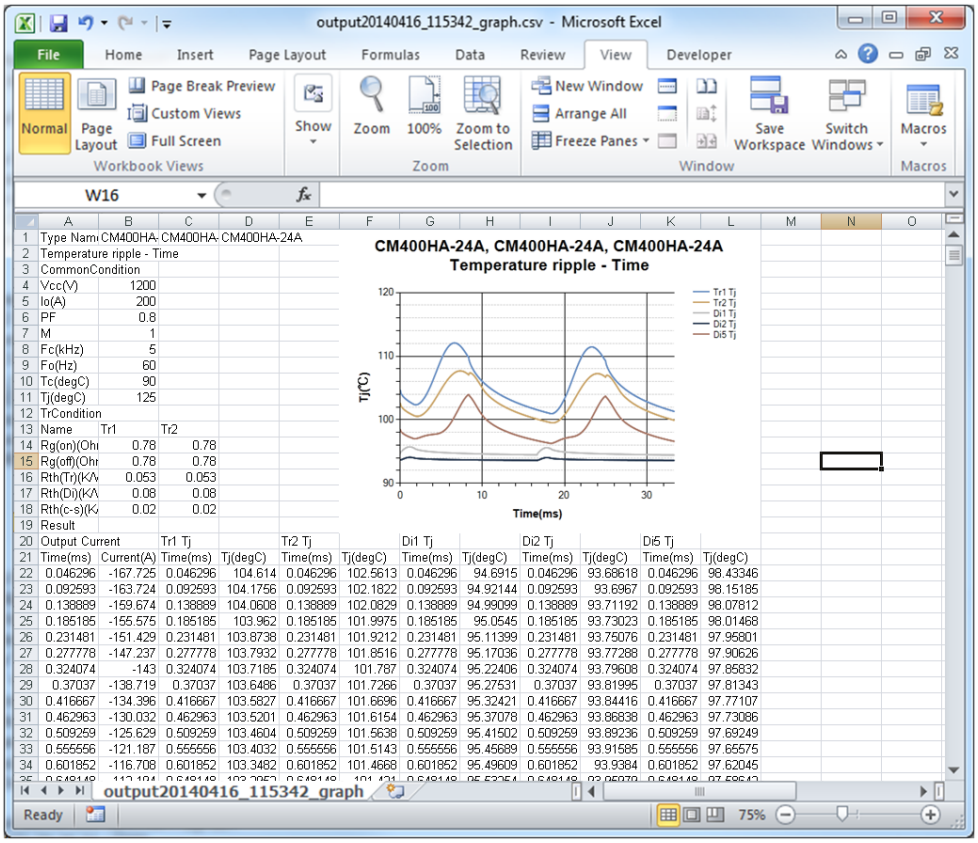

Adding or removing elements of the devices is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at the upper left.




Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save as Image file]

For example.) It is possible to open the CSV file of text data and then paste PNG data of graph into tha file.




Maximize the window and expand graph width is recommended for getting better graph resolution.

## 5.3 Opening previous designs

### 5.3.1 Open the last saved design

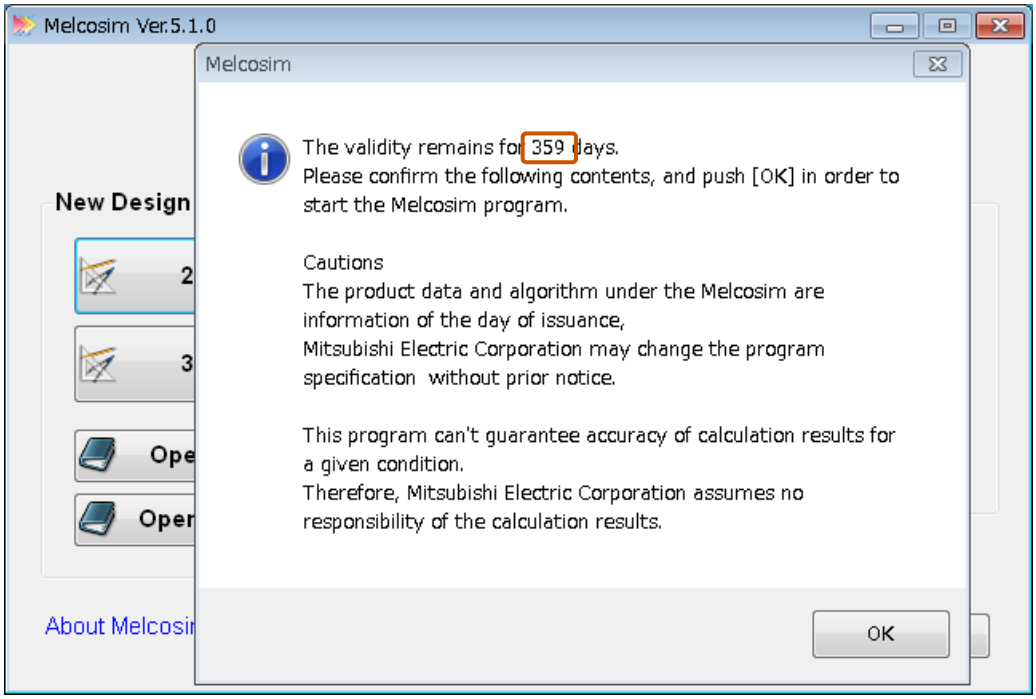

In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

### 5.3.2 Open the saved design in folders

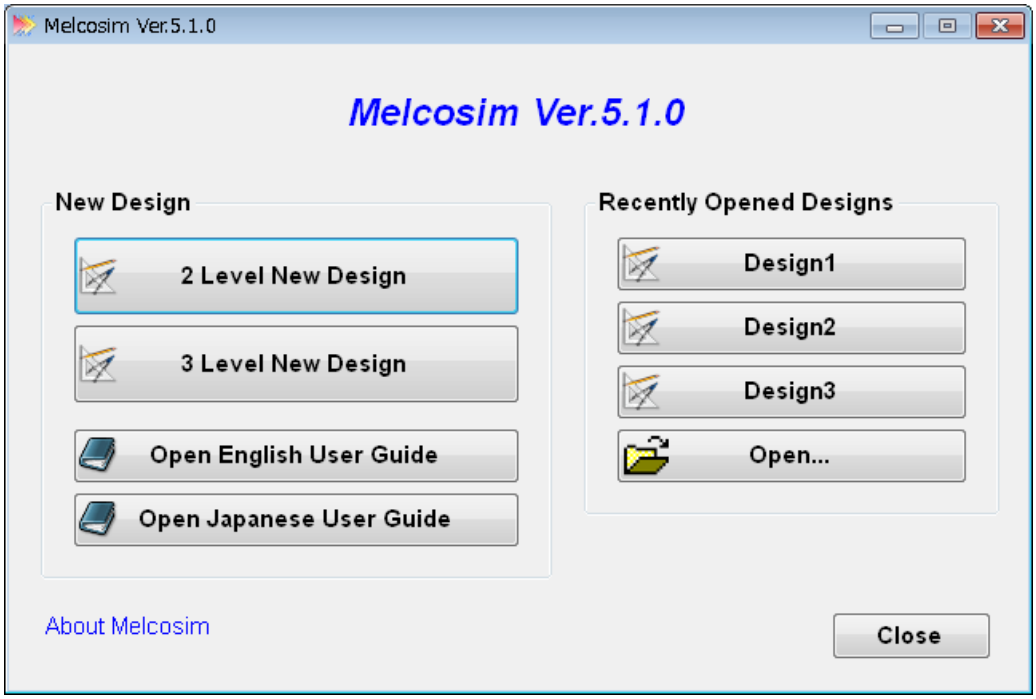
# 6 Loss calculation in T Type NPC configration

## 6.1 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.




Click OK , then move to the main window in the case that the expiration date is still valid.



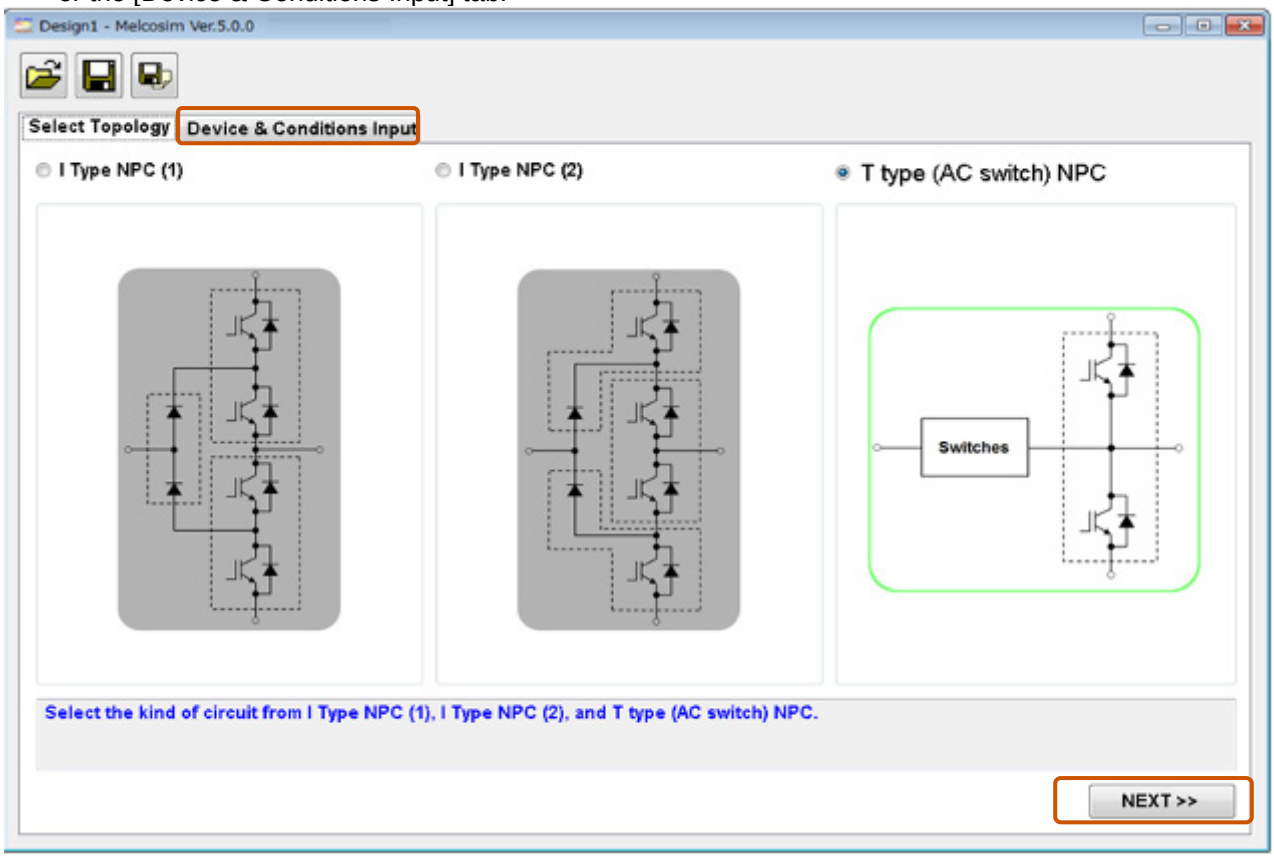
## 6.2 New design calculation

### 6.2.1 Main window

Click on the [3 Level New Design] button.

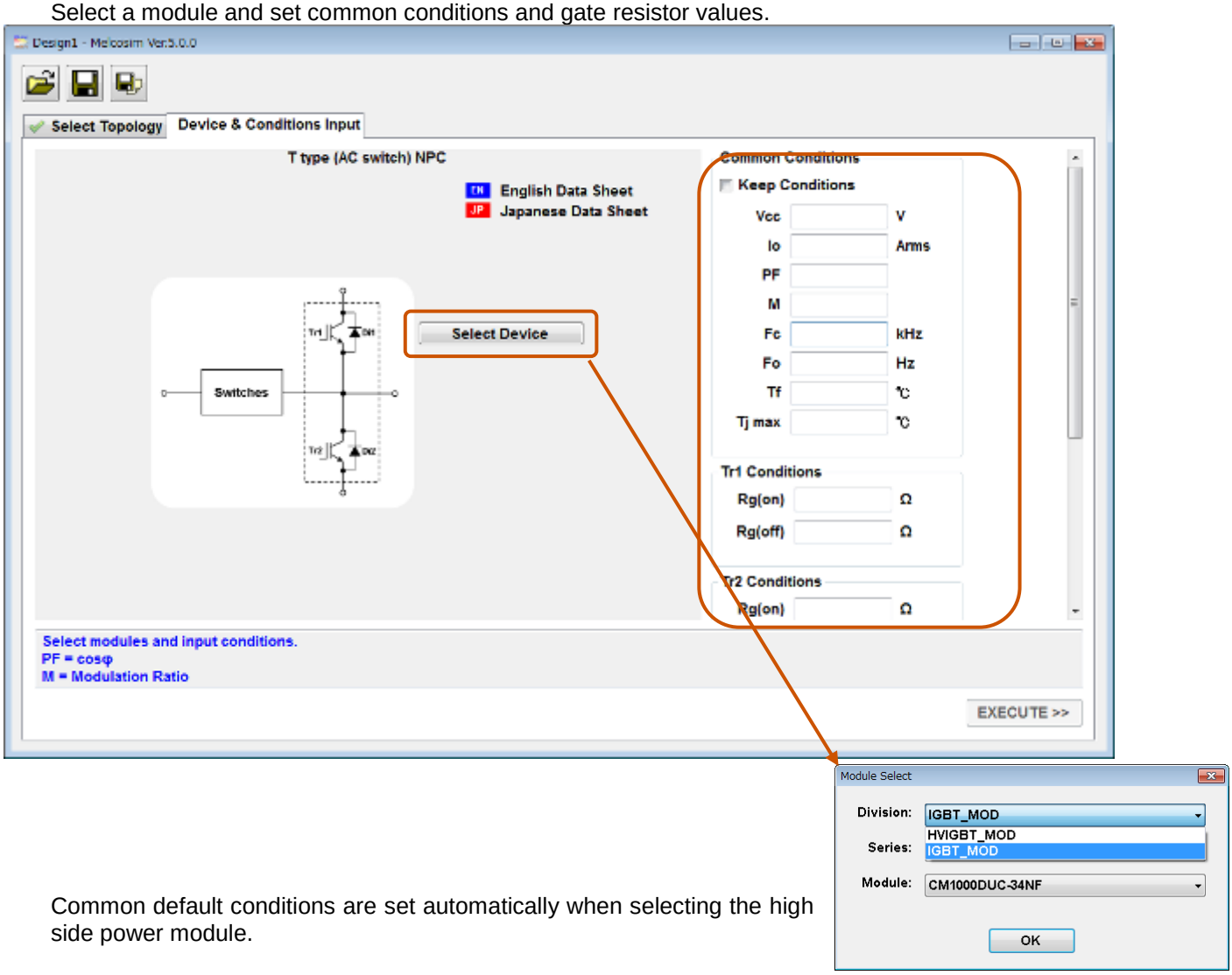

### 6.2.2 Select topology selection window

Click on the button of the [T Type (AC switch) NPC] or on the schematic area and click the [NEXT>>] button or the [Device & Conditions Input] tab.

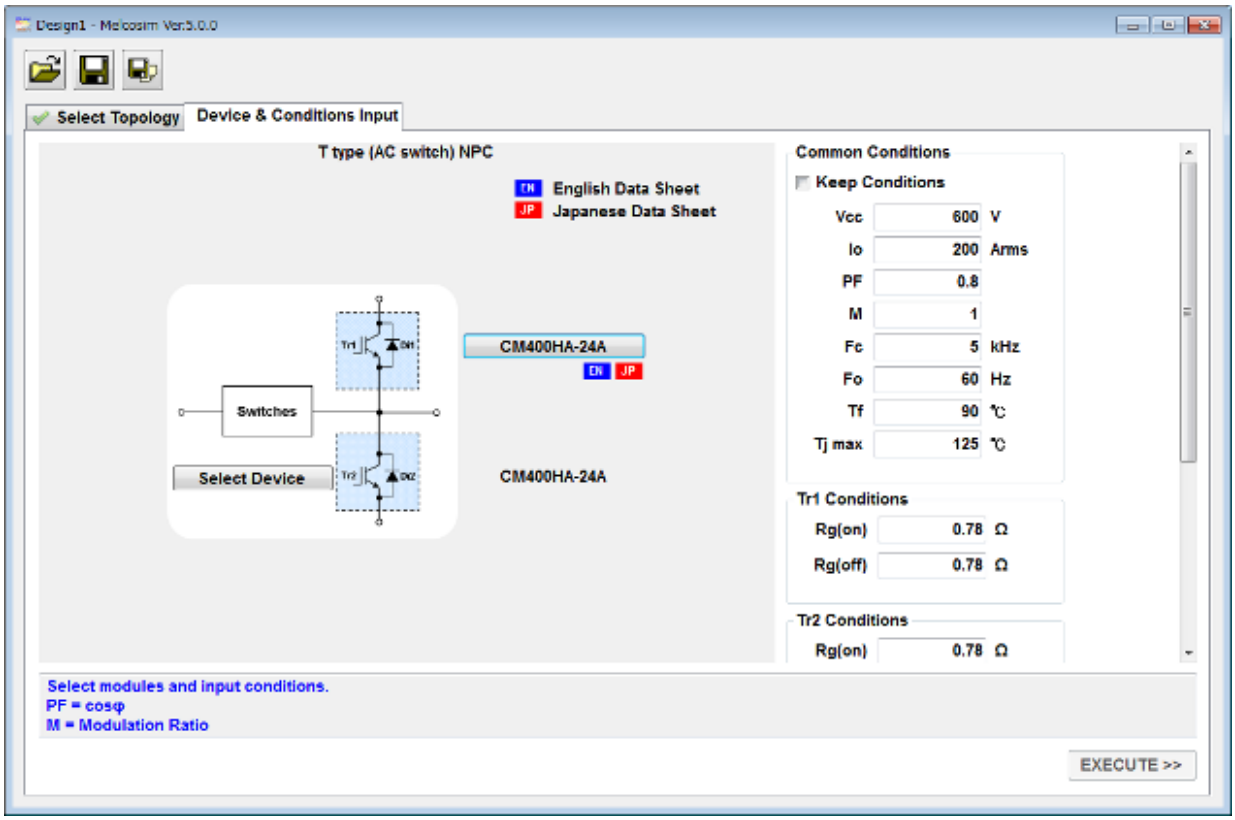


### 6.2.3 Device & conditions input window

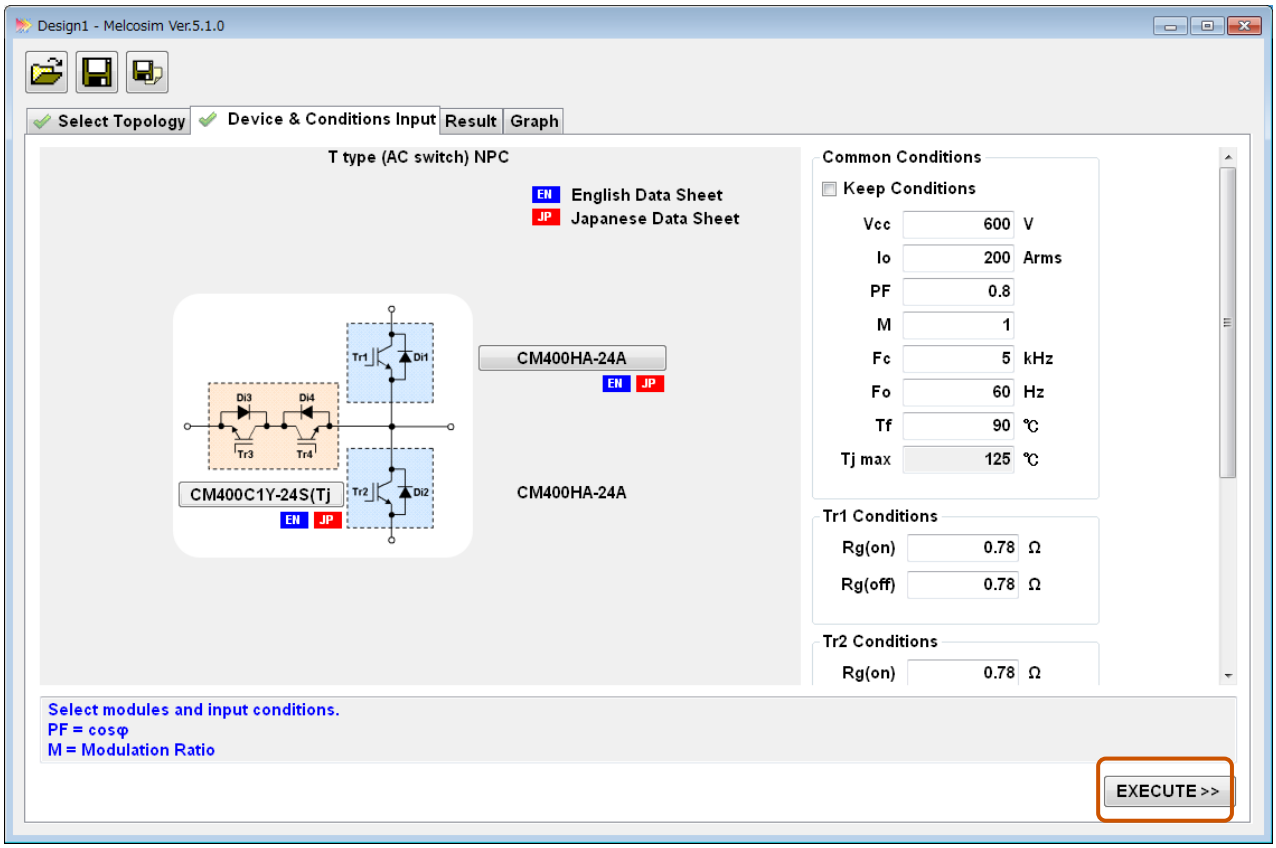
Select a module and set common conditions and gate resistor values.




Common default conditions are set automatically when selecting the high side power module.

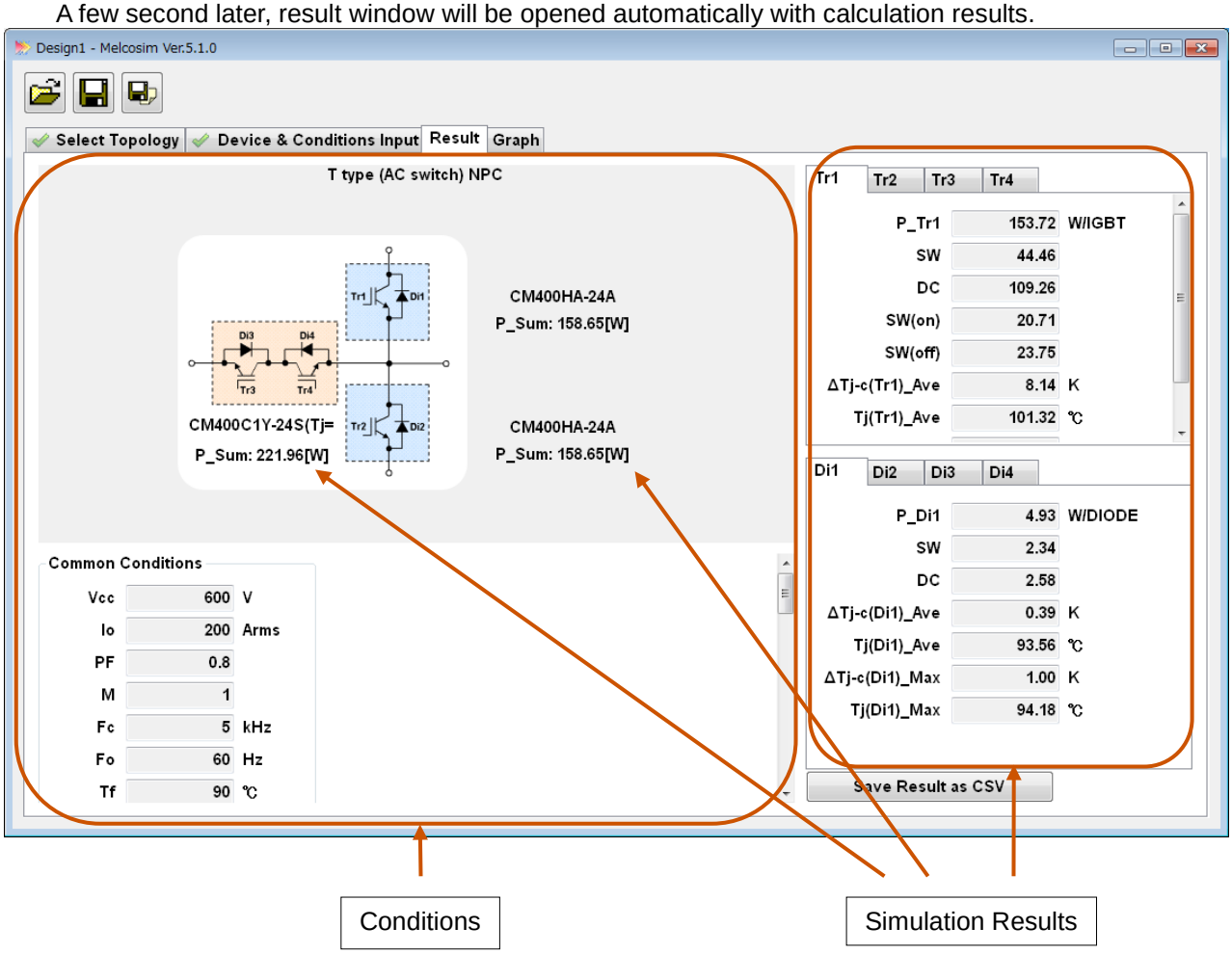



After selecting all devices and having set all conditions, click the [EXECUTE>>] button.
NOTE) In case of incomplete device or data conditions, the [EXECUTE>>] button is not available.



### 6.2.4 Result window

A few second later, result window will be opened automatically with calculation results.

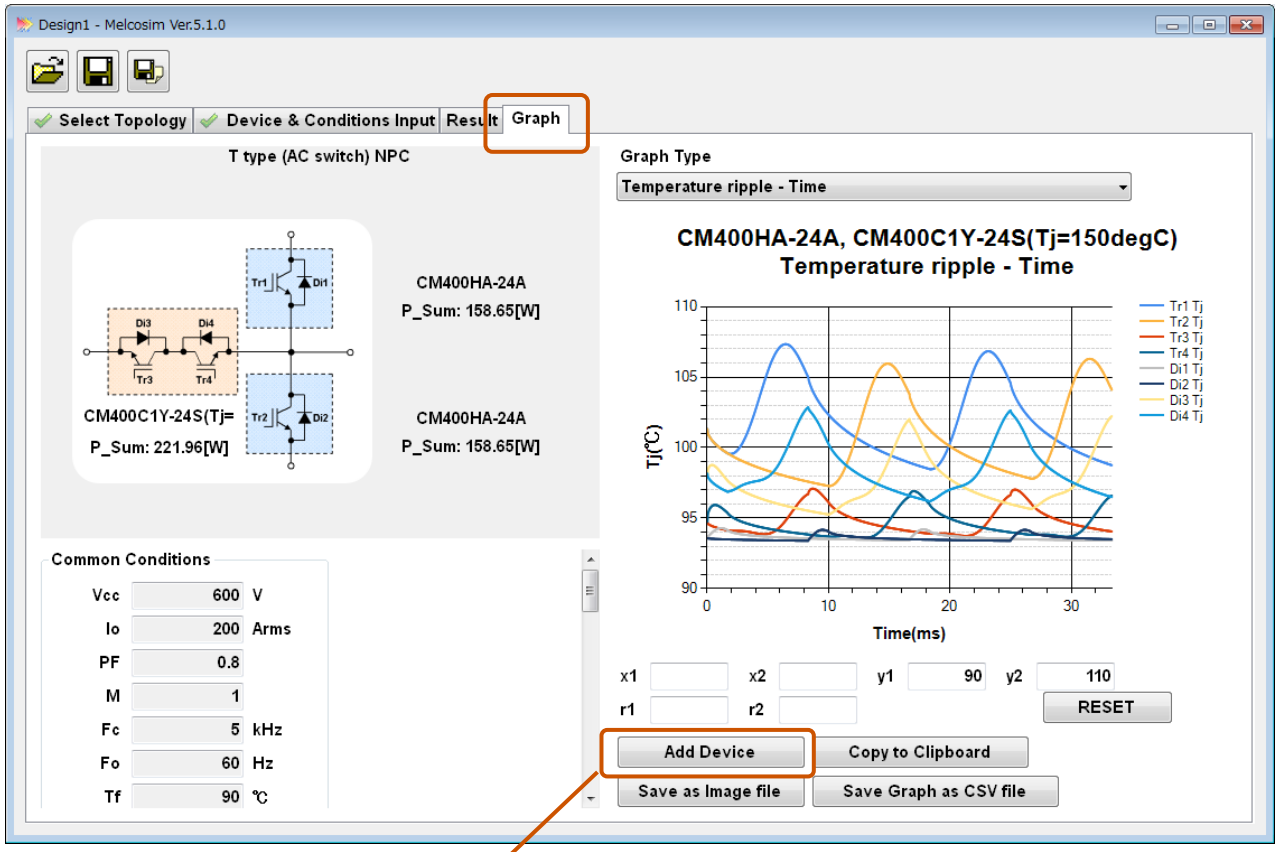


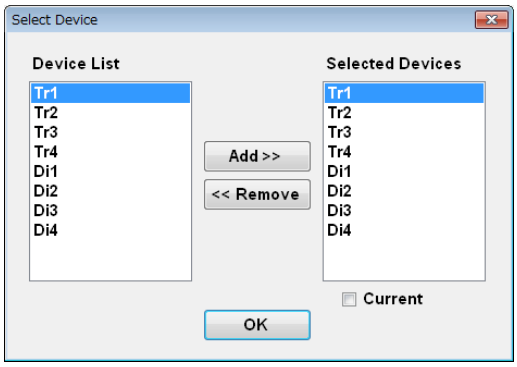

Conditions

Simulation Results

### 6.2.5 Graph window

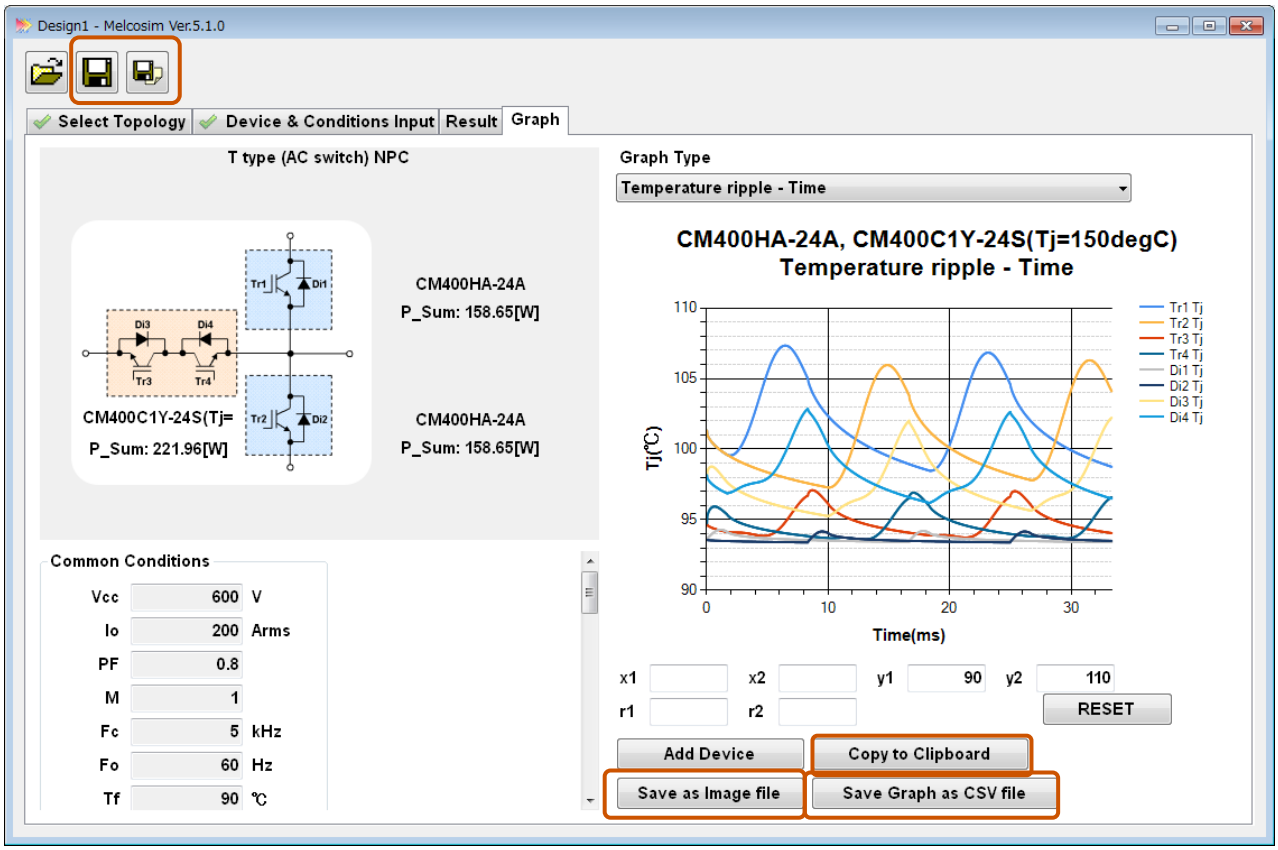
Calculation results are shown visually in the graph window.



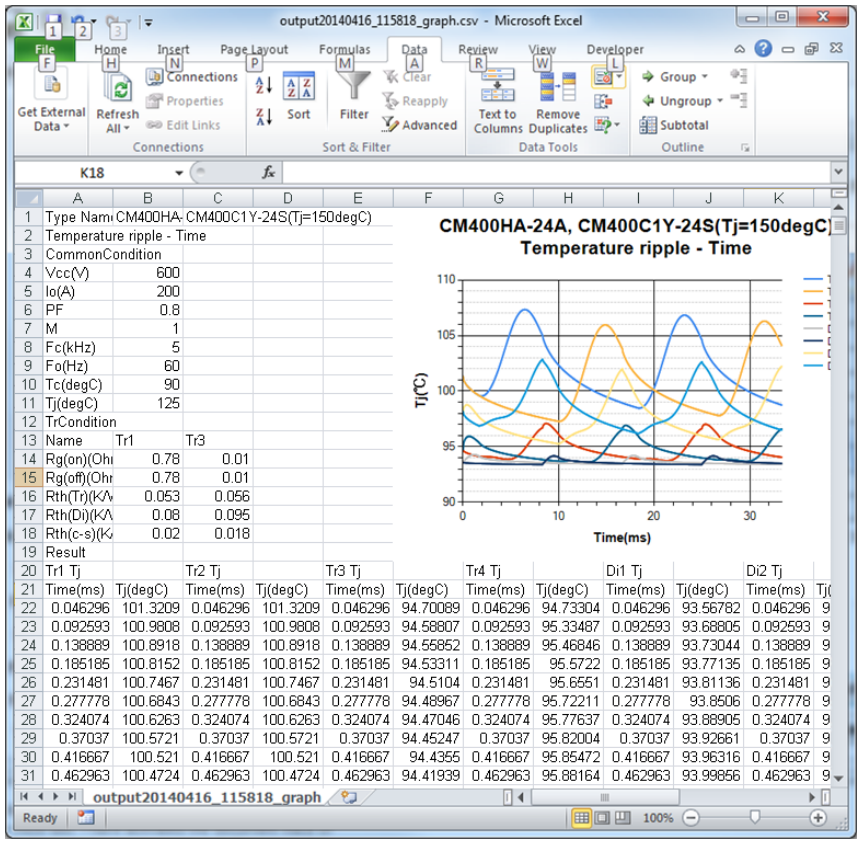

Adding or removing elements of the device is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at upper left side of the screen.




Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save to Image file]

For example: It is possible to open the CSV file of text data and then paste PNG data of graph into that file.




Maximize the window and expand graph width is recommended for getting better graph resolution.

## 6.3 Opening previous designs

### 6.3.1 Open the latest saved design


In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

### 6.3.2 Open the saved design in folders

# 7 Topology (Modulation method)

## 7.1 2-level inverter

### 7.1.1 Sinusoidal modulation

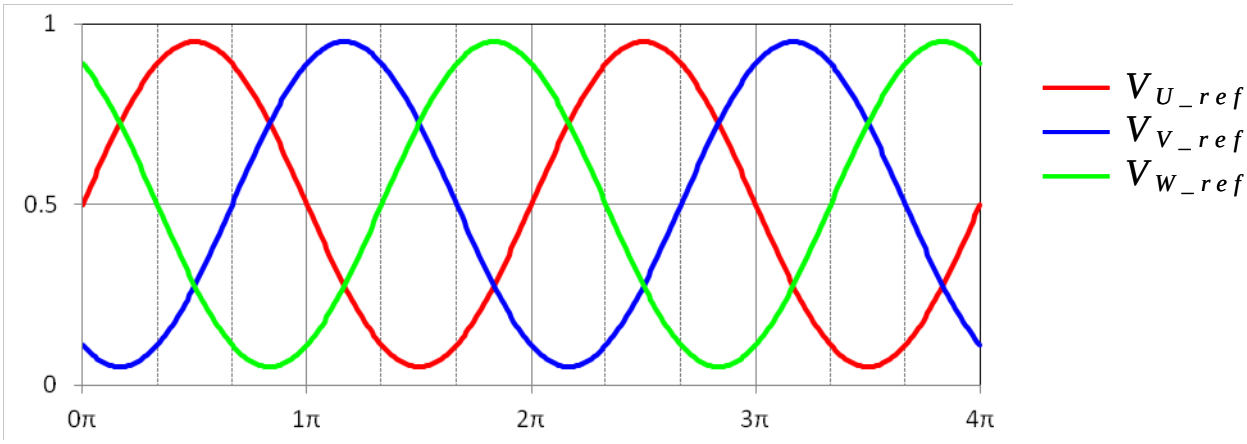
The most basic modulation method creates a sinusoidal output waveform of each phase.
The reference voltage for U-phase, V-phase and W-phase as follow.

$$V_{U\_ref} = M\frac{V_{CC}}{2}\left(\sin\theta + \frac{1}{2}\right)$$

$$V_{V\_ref} = M\frac{V_{CC}}{2}\left(\sin\left(\theta - \frac{2\pi}{3}\right) + \frac{1}{2}\right)$$

$$V_{W\_ref} = M\frac{V_{CC}}{2}\left(\sin\left(\theta + \frac{2\pi}{3}\right) + \frac{1}{2}\right)$$

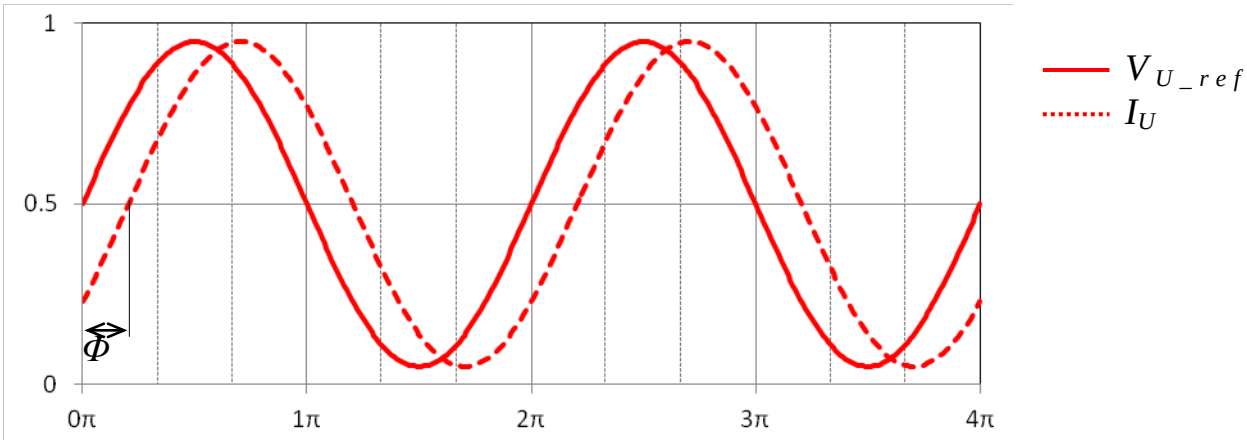
M: Modulation ratio, $V_{CC}$: DC bus voltage



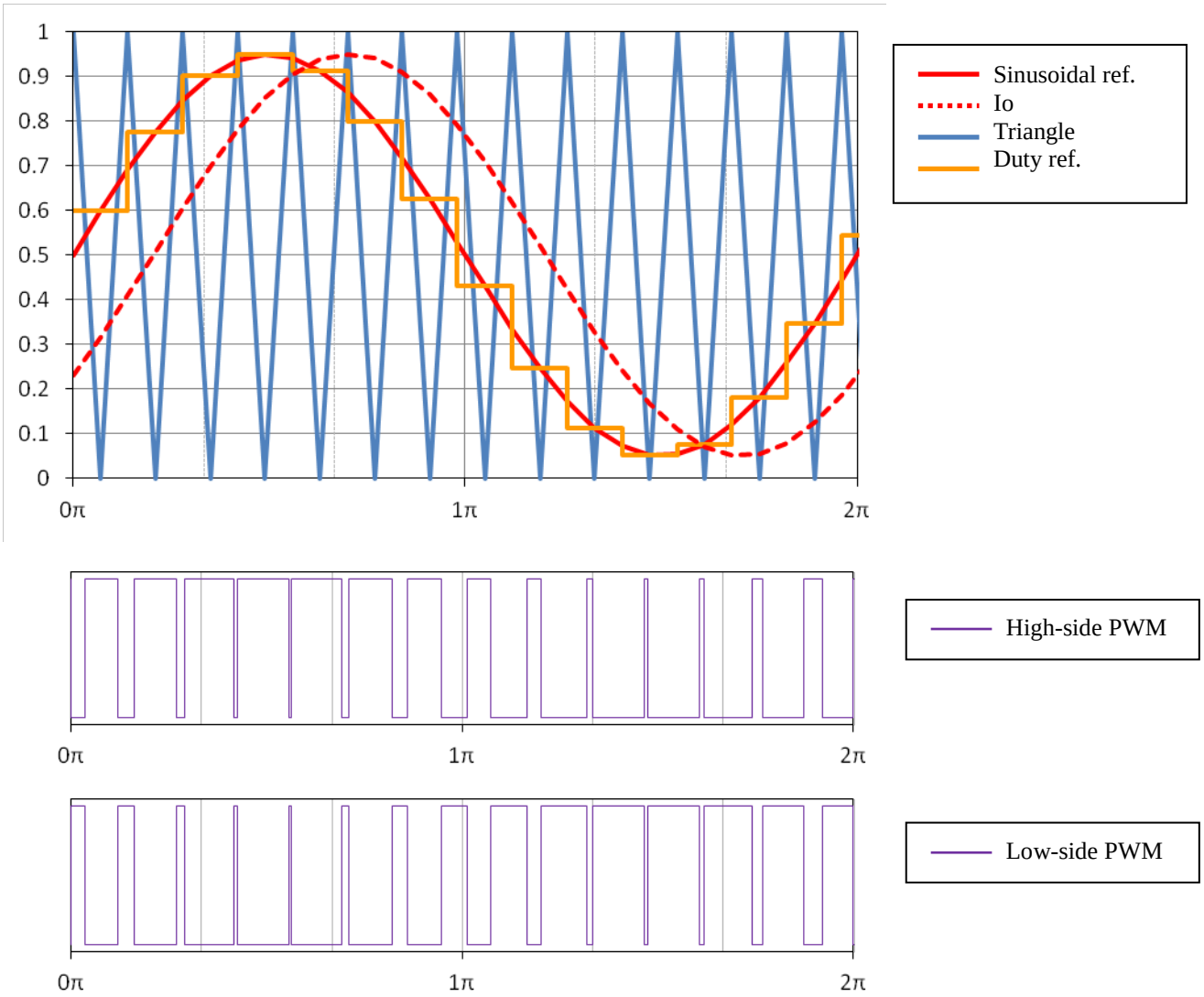

Interphase voltage also sinusoidal.

$$V_{U\text{-}V} = V_{U\_ref} - V_{V\_ref} = M\frac{V_{CC}}{2}\sin\theta - M\frac{V_{CC}}{2}\sin\left(\theta - \frac{2\pi}{3}\right) = \frac{\sqrt{3}}{2}M \times V_{CC}\sin\left(\theta + \frac{\pi}{6}\right)$$

Outut current Io is calculated by cos $\Phi$ from reference voltage.



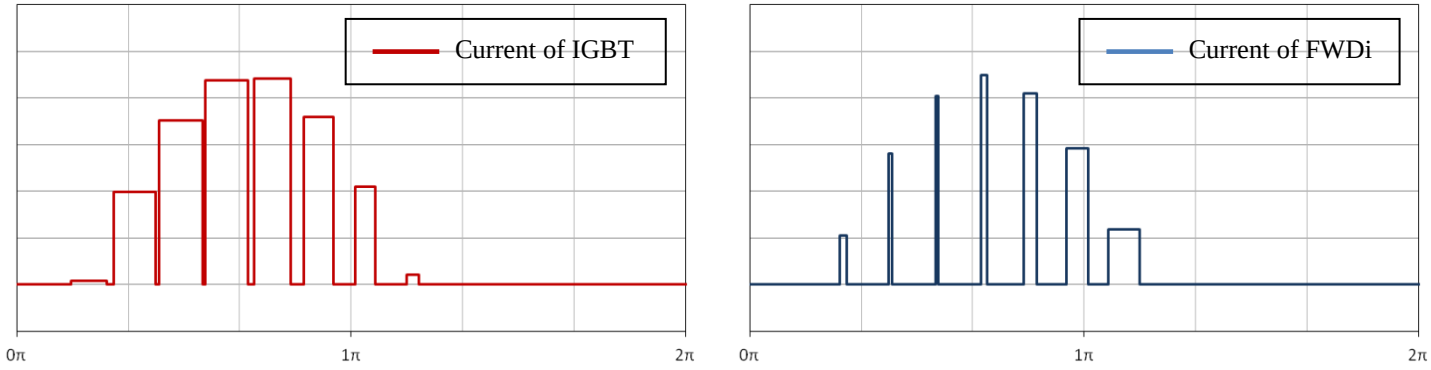
The corresponding PWM Duty is simply calculated by comparing the count value of an up-down counter of micro controller with a reference voltage which is sinusoidal in this case.
Dead time as applied between high and low side in real PWM halfbridge switching operations is not considered for the loss simulation.




The power loss is calculated by the following analytical equation taking into account the interval mean values of the saturation voltages / forward voltage drops and currents being integrated / summed up over the entire cycle. By consideration of the duty cycle in that equation the mean power of each device can be calculated as follows:

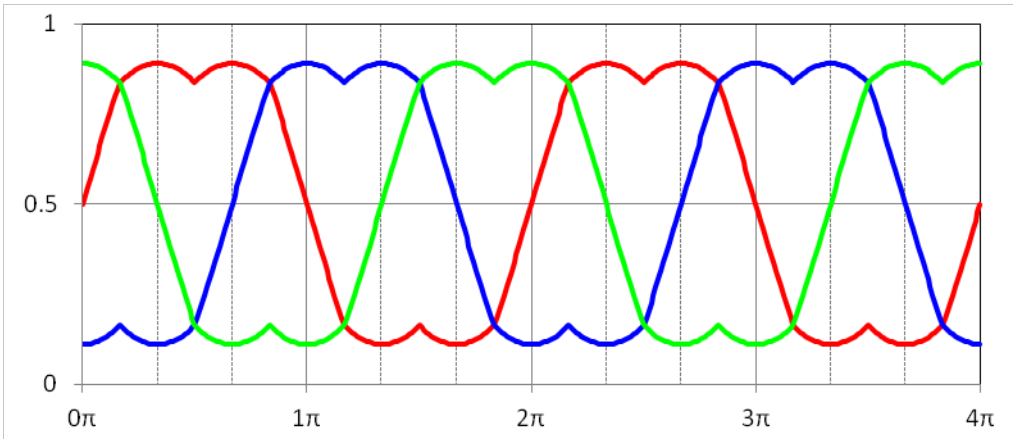
$$P_{DC(\mathrm{IGBT})} = \sum_{phase=0}^{2p} \left( I_C \cdot V_{CE(sat)@I_C} \cdot Duty(on) \right) \quad , \quad P_{DC(FWDi)} = \sum_{phase=0}^{2p} \left( I_C \cdot V_{EC@I_C} \cdot Duty(off) \right)$$

$$P_{SW(\mathrm{IGBT})} = \sum_{phase=0}^{2p} \left( E_{on@I_C} + E_{off@I_C} \right) \quad , \quad P_{SW(FWDi)} = \sum_{phase=0}^{2p} E_{rr@I_C}$$

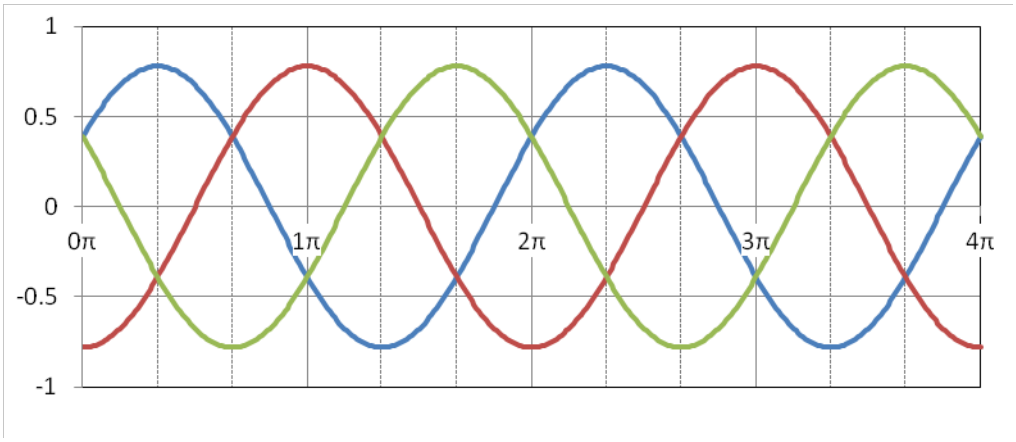


### 7.1.2 SVPWM(Space Vector PWM) modulation

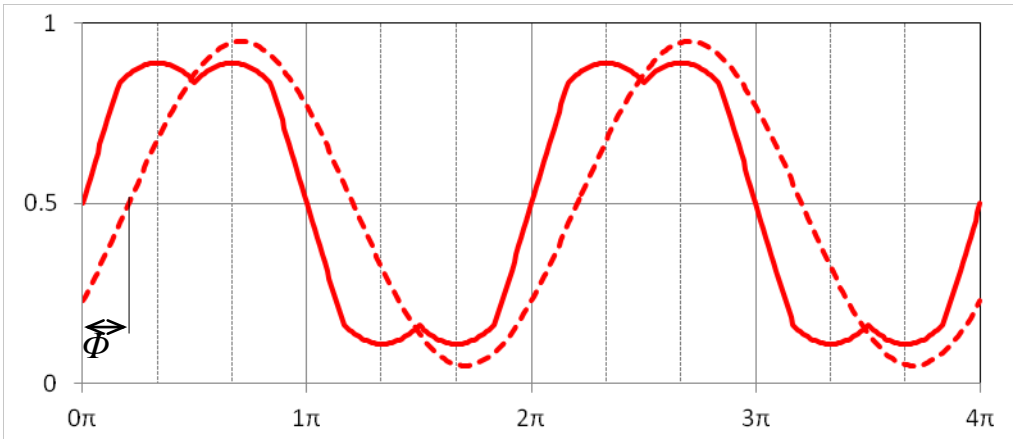
The reference voltage of SVPWM is shown in the following drawing.




While the reference voltage of each phase does not show a sinusoidal waveform the inter phase voltage has got the desired sinusoidal voltage waveform shape.




From that the out current Io is calculated by a cos $\Phi$ from the reference voltage.

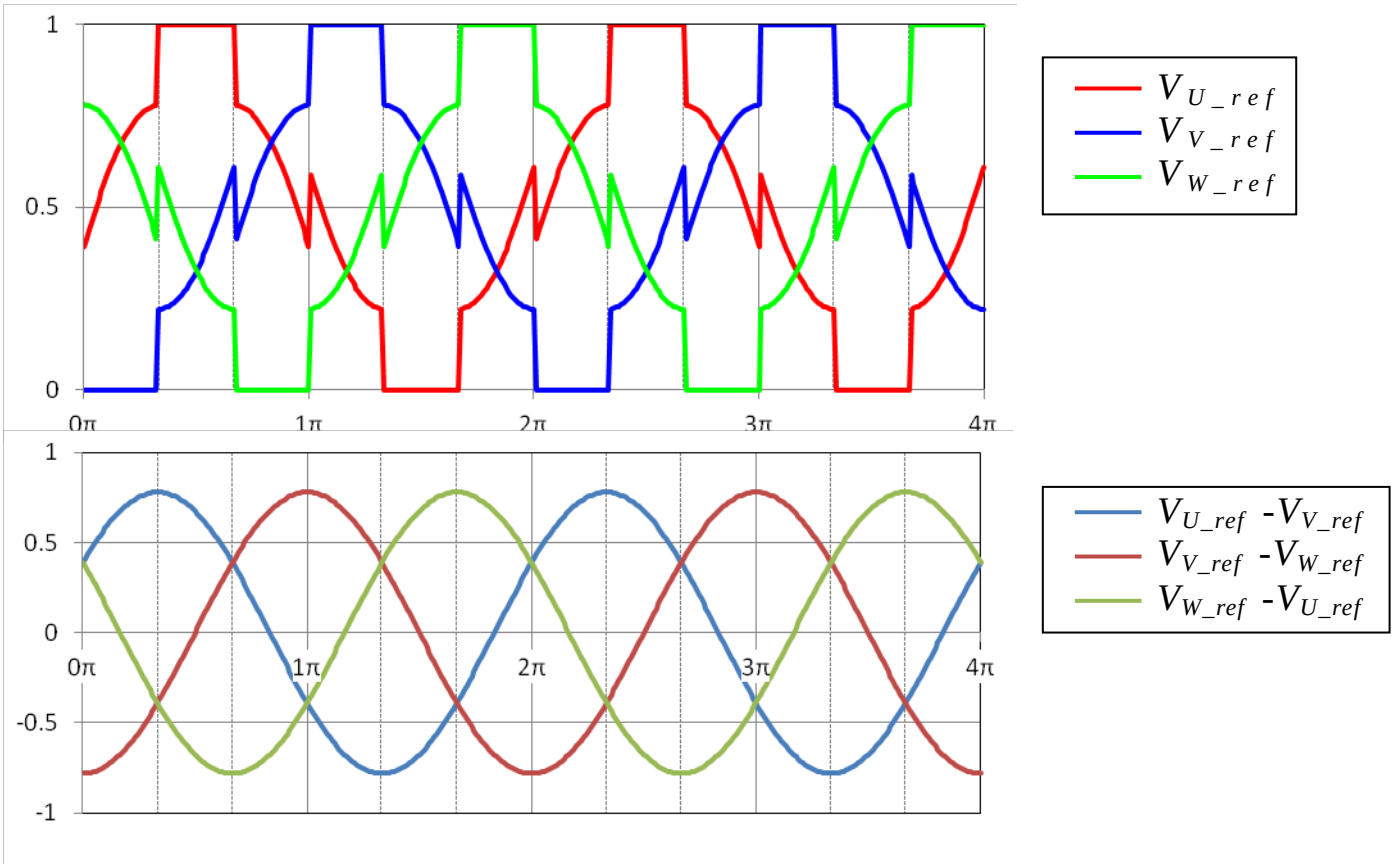



The modulation ratio of this SVPWM is defined to be even output voltage with sinusoidal modulation.
So, maximum modulation ratio is 1.1547($= 2/\sqrt{3}$).

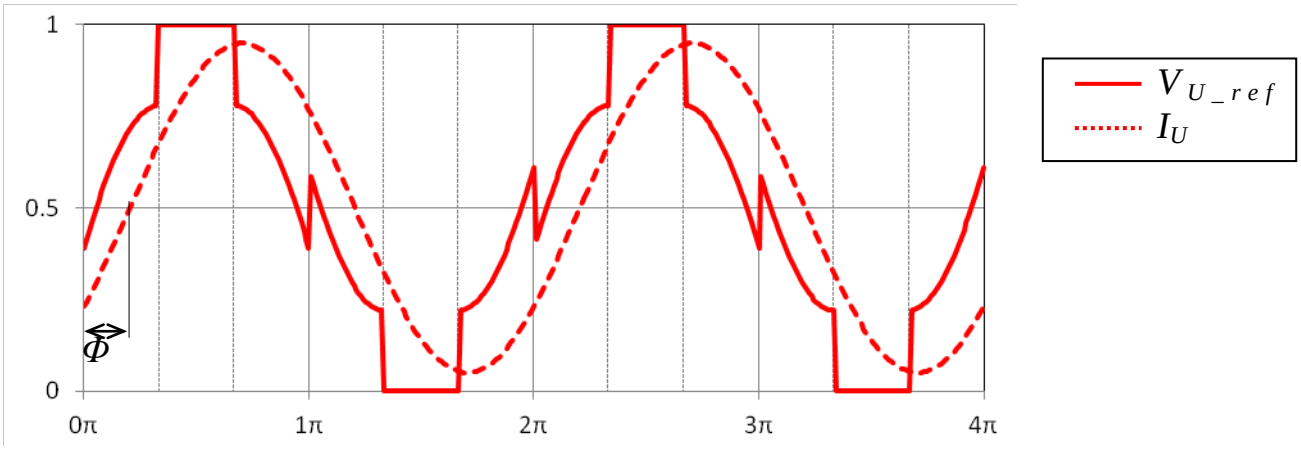
Refer to 7.1.1 for PWM duty calculation.

### 7.1.3 2 phase modulation

In two phase are modulation one phase is fixed and and the two remaining phases are performing the PWM.
This approach may save switching loss compared with classical 3-switch modulation.
The reference voltage is not sinusoidal waveform but the interphase voltage has got a sinusoidal waveform shape.



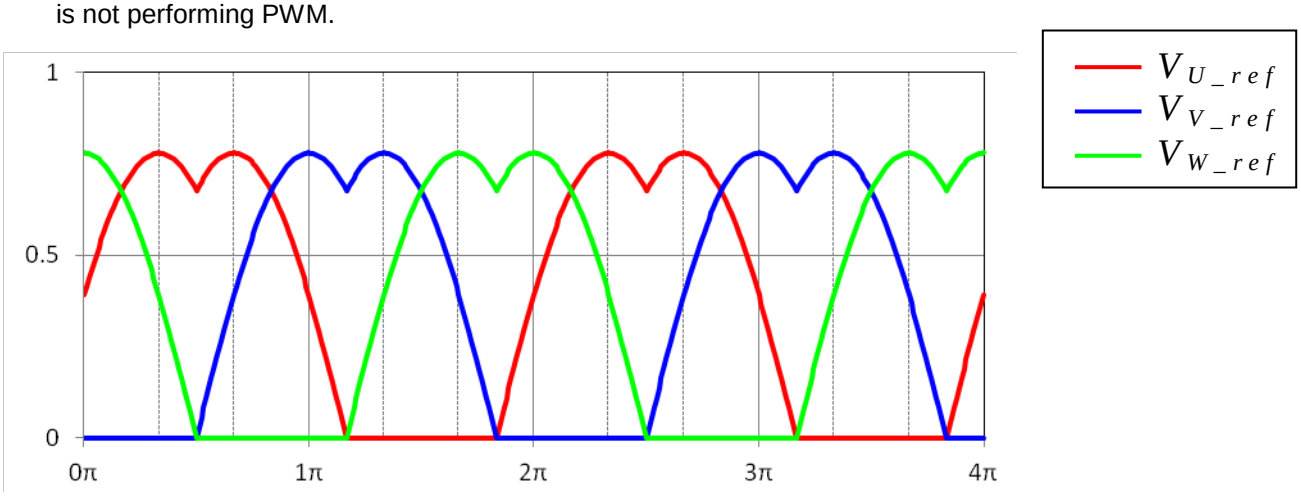

Ouput current Io is calculated by cos $\Phi$ from the reference voltage.



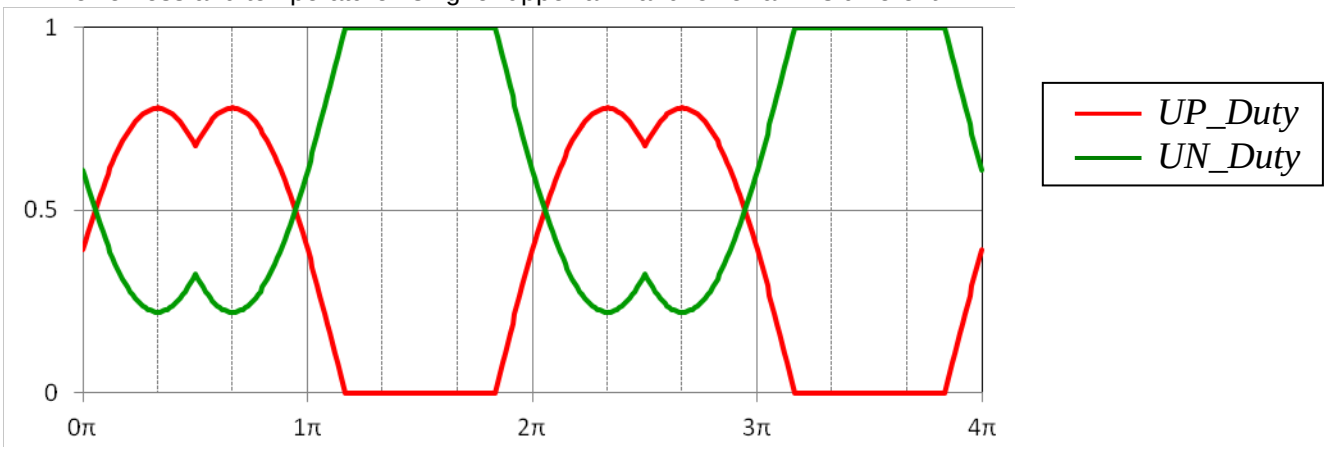

The modulation ratio of this 2 phase modulation approach is defined to be even output voltage with sinusoidal modulation.
So, maximum modulation ratio is 1.1547($= 2/\sqrt{3}$).
Refer to 7.1.1 forPWM duty calculation.

### 7.1.4 2 phase II modulation

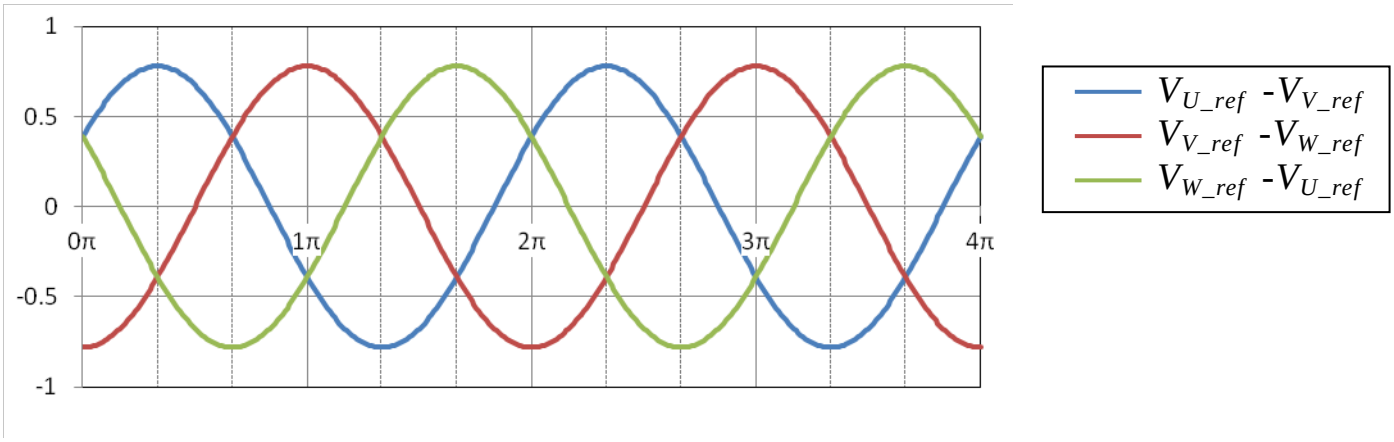
This is a space vector modulation scheme where two phases are modulating and the remaining phases is not performing PWM.



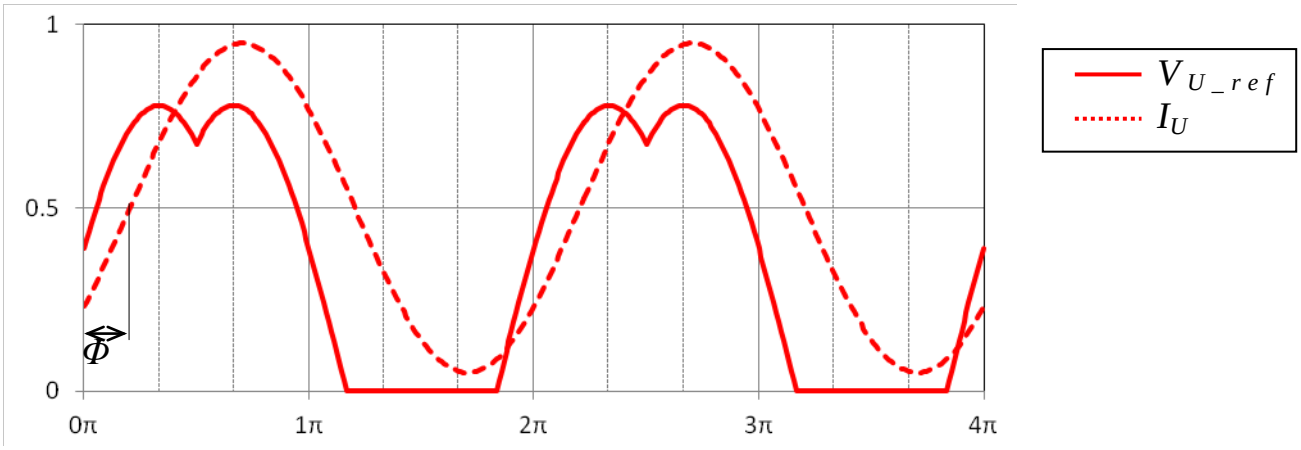

This reference voltage is for the PWM duty of the upper-arm switches and its complement PWM duty is applied for the lower-arm switching elements.
Power loss and temperature rising for upper-arm and lower-arm is different.




The reference voltage is not sinusoidal waveform but interphase voltage is sinusoidal waveform.



The output current Io is calculated by cos $\Phi$ from reference voltage.



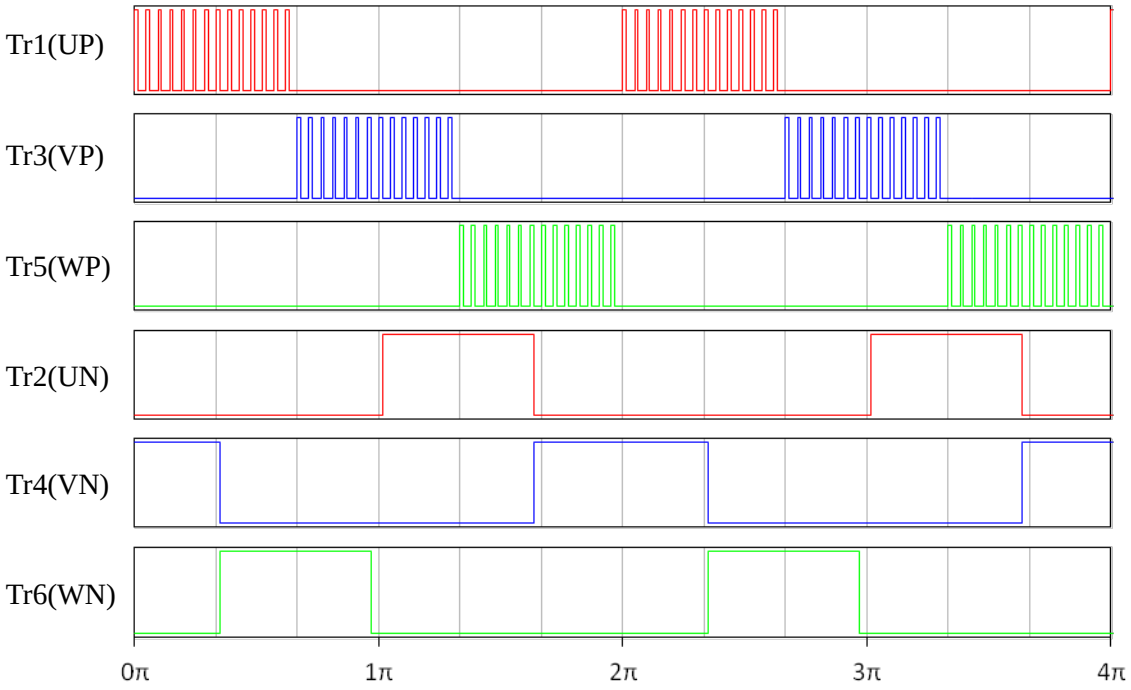

The modulation ratio of this 2 phase II modulation approach is defined to be even output voltage with sinusoidal modulation.

So, maximum modulation ratio is 1.1547($= 2/\sqrt{3}$).

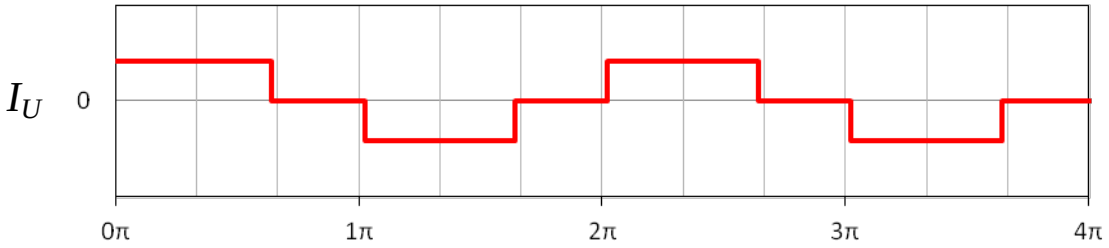
Refer to 7.1,1 for PWM duty calculation.

### 7.1.5 High-side chopping

In this PWM scheme the upper-arm is chopping for 120 degrees ( π /3) of 360 degrees(2 π ) and the lower-arm turns on in for 120 degrees( π /3) of 360 degrees(2 π ) with a shift of 180 degrees( π ) to the upper-arm.
There is a constant duty in one cycle.




The output current Io is defined as rectangular current wave shape as follows.




The power loss of the upper-arm IGBT is the sum of DC loss and switching loss.
For this PWM scheme the following equations provide the base for the loss calculation:

$$P_{DC(IGBT\_UP)} = I_C \cdot V_{CE(sat)} \cdot Duty(on) \quad , \quad P_{SW(IGBT\_UP)} = (E_{on} + E_{off}) \cdot f_{SW}$$

$$P_{IGBT\_UP} = \frac{1}{3} \cdot \left(P_{DC(IGBT\_UP)} + P_{SW(IGBT\_UP)}\right)$$

The power loss of the upper-arm's FWDi is nearly zero.

$$P_{FWDi\_UP} = 0$$

Lower-arm's IGBT power loss is DC only.

$$P_{IGBT\_UN} = \frac{1}{3} \cdot I_C \cdot V_{CE(sat)}$$

The power loss of the lower-arm's FWDi is the sum of DC loss and switching loss.

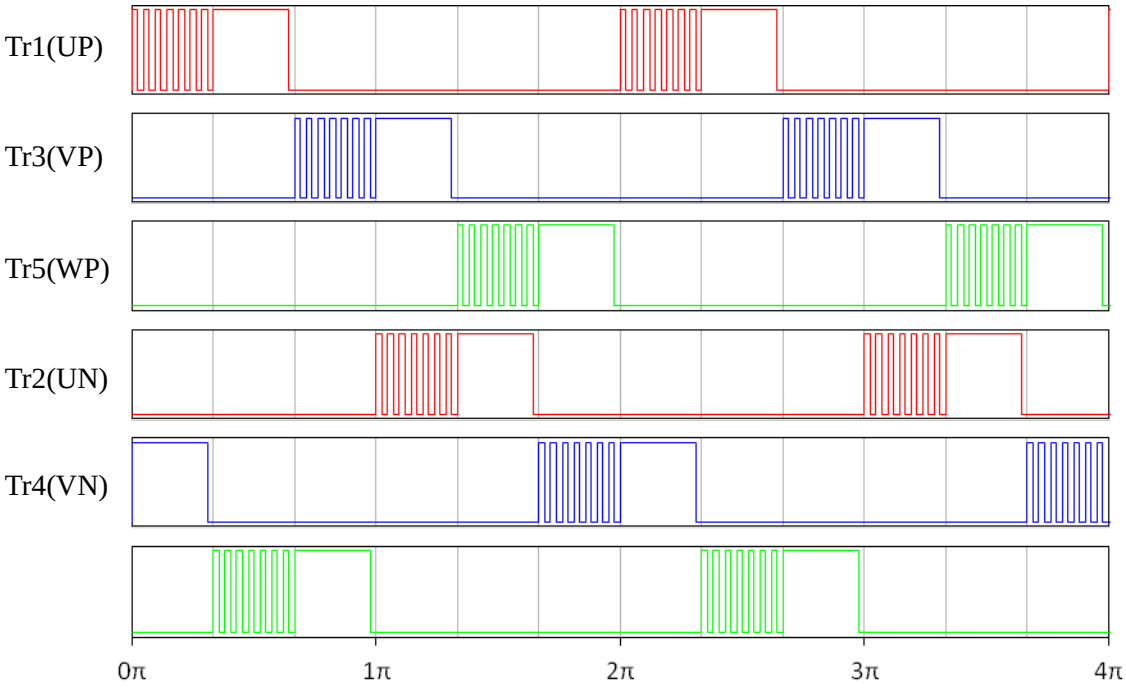
$$P_{DC(FWDi\_UN)} = I_C \cdot V_{EC} \cdot Duty(off) \quad , \quad P_{SW(FWDi\_UN)} = E_{rr} \cdot f_{SW}$$

$$P_{FWDi\_UN} = \frac{1}{3} \cdot \left(P_{DC(FWDi\_UN)} + P_{SW(FWDi\_UN)}\right)$$

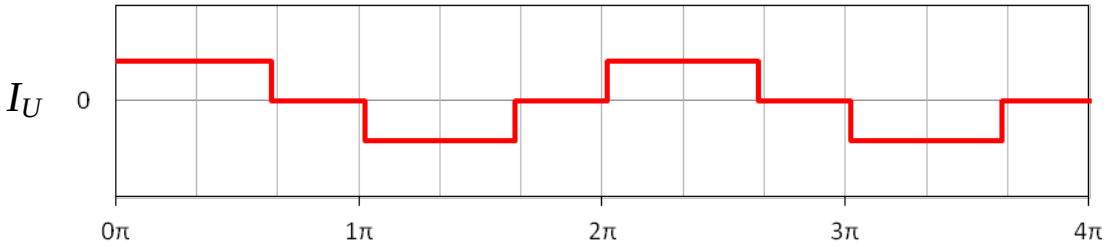
Then the power loss and temperature rise for upper-arm and lower-arm is different.

### 7.1.6 First half chopping

This PWM scheme incorporates a current conducting period of 120degrees and a chopping operation in the first 60 degrees of the cycle.
There is a constant duty in one cycle.




The output current Io is defined as rectangular current wave shape as follows.




The power loss of the upper-arm IGBT is the sum of DC loss and switching loss. For this PWM scheme the following equations provide the base for the loss calculation:

$$P_{DC(IGBT\_chopping)} = I_C \cdot V_{CE(sat)} \cdot Duty(on) \quad , \quad P_{SW(IGBT)} = (E_{on} + E_{off}) \cdot f_{SW} \quad , \quad P_{DC(IGBT\_flat)} = I_C \cdot V_{CE(sat)}$$

$$P_{IGBT} = \frac{1}{6} \cdot \left(P_{DC(IGBT\_chopping)} + P_{SW(IGBT)} + P_{DC(IGBT\_flat)}\right)$$

Power loss of FWDi is sum of DC loss and switching loss.

$$P_{DC(FWDi)} = I_C \cdot V_{EC} \cdot Duty(off) \quad , \quad P_{SW(FWDi)} = E_{rr} \cdot f_{SW}$$

$$P_{FWDi} = \frac{1}{6} \cdot \left(P_{DC(FWDi)} + P_{SW(FWDi)}\right)$$

A balanced power loss are generated in upper-arm and lower-arm by this PWM approach.

### 7.1.7 Down chopper / motor lock operation

In down chopper (buck) and rotor lock operation the power loss and temperature rise is calculated in the same way.
The duty is calculated from the input voltage Vi and the output voltage Vo.
The Input current Ii is calculated automatically from Io and the duty respectively.

$$Duty = \frac{V_O}{V_i} \quad , \quad \mathrm{I}_i = Duty' \; I_O$$

Vo is recalculated whenever the input “Duty” is changed. Hence,
$V_O \pounds V_i$ is the simulation range in buck converter.

### 7.1.8 Boost chopper operation

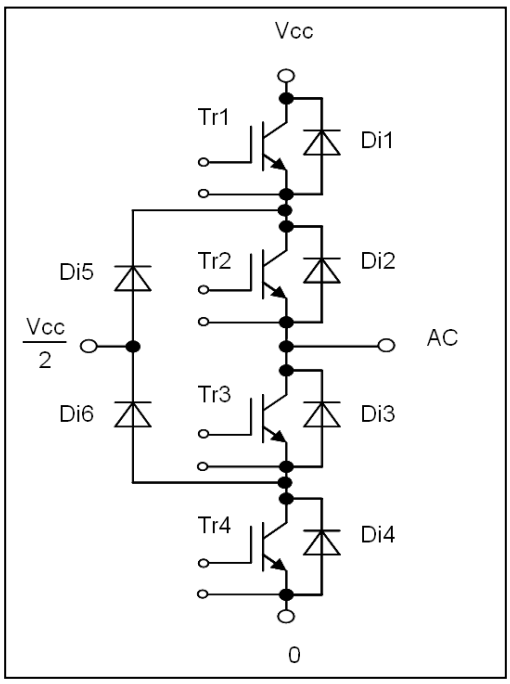
The boost chopper’s mode calculation power loss and temperature rise is calculated as follows:
The duty is calculated from the input voltage Vi and the output voltage Vo.
The input current Ii is calculated automatically from Io and the duty respectively.

$$Duty = \frac{V_O - V_i}{V_i} \quad , \quad I_i = \frac{I_O}{Duty}$$

Vo is recalculated whenever a value is written to the “Duty” entry field. Hence,
$V_i \pounds V_O$ is the simulation range in buck converter.

## 7.2 3-level inverter

### 7.2.1 I Type NPC



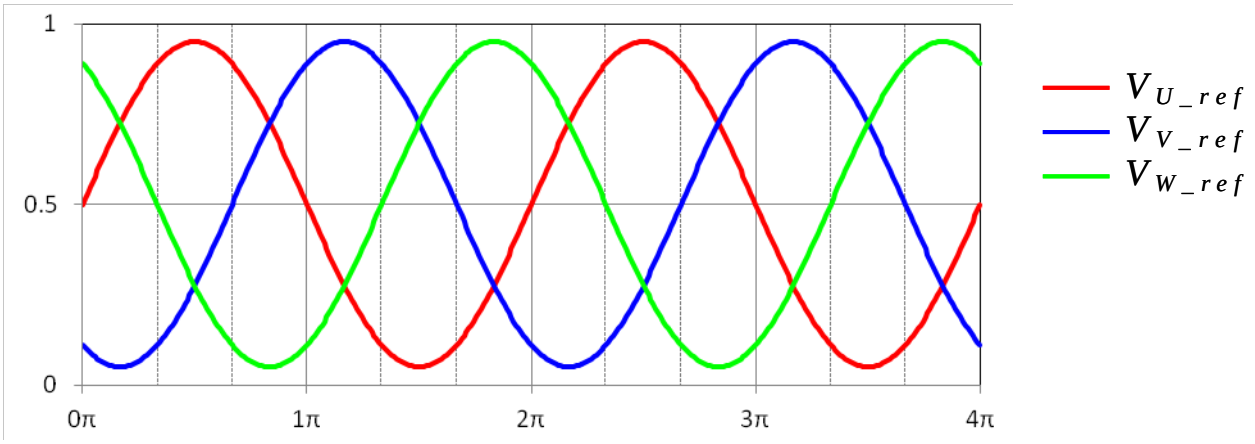

The most basic modulation method creates a sinusoidal output waveform of each phase by using 3-level inverter topology.
Free Wheeling Diodes (Di1 to Di4) are anti-parallel connection to IGBTs (Tr1 to Tr4) and they are connected serially with Diodes (Di5, Di6) as right drawing (one-leg).
The fuature of this topology is able to use half rating voltage devices and half dv/dt from 2-level inverter.
The reference voltage for U-phase, V-phase and W-phase as follow same as 2-level inverter.

$$V_{U\_ref} = M\frac{V_{CC}}{2}\left(\sin\theta + \frac{1}{2}\right)$$

$$V_{V\_ref} = M\frac{V_{CC}}{2}\left(\sin\left(\theta - \frac{2\pi}{3}\right) + \frac{1}{2}\right)$$

$$V_{W\_ref} = M\frac{V_{CC}}{2}\left(\sin\left(\theta + \frac{2\pi}{3}\right) + \frac{1}{2}\right)$$

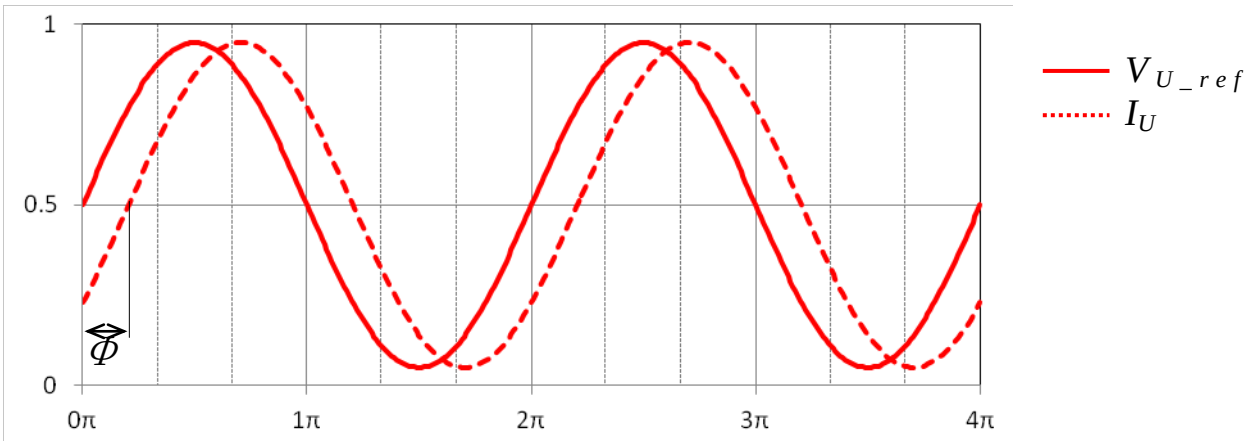
M: Modulation ratio, $V_{CC}$: DC bus voltage



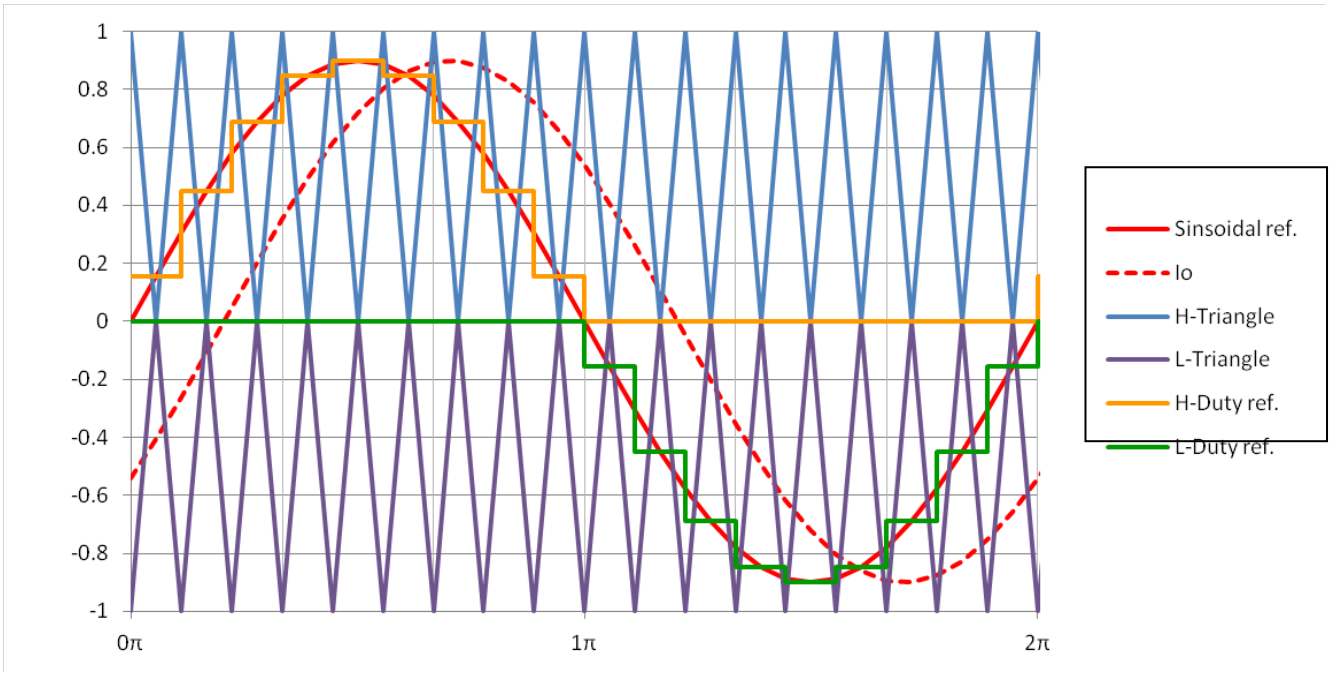

Interphase voltage also sinusoidal.

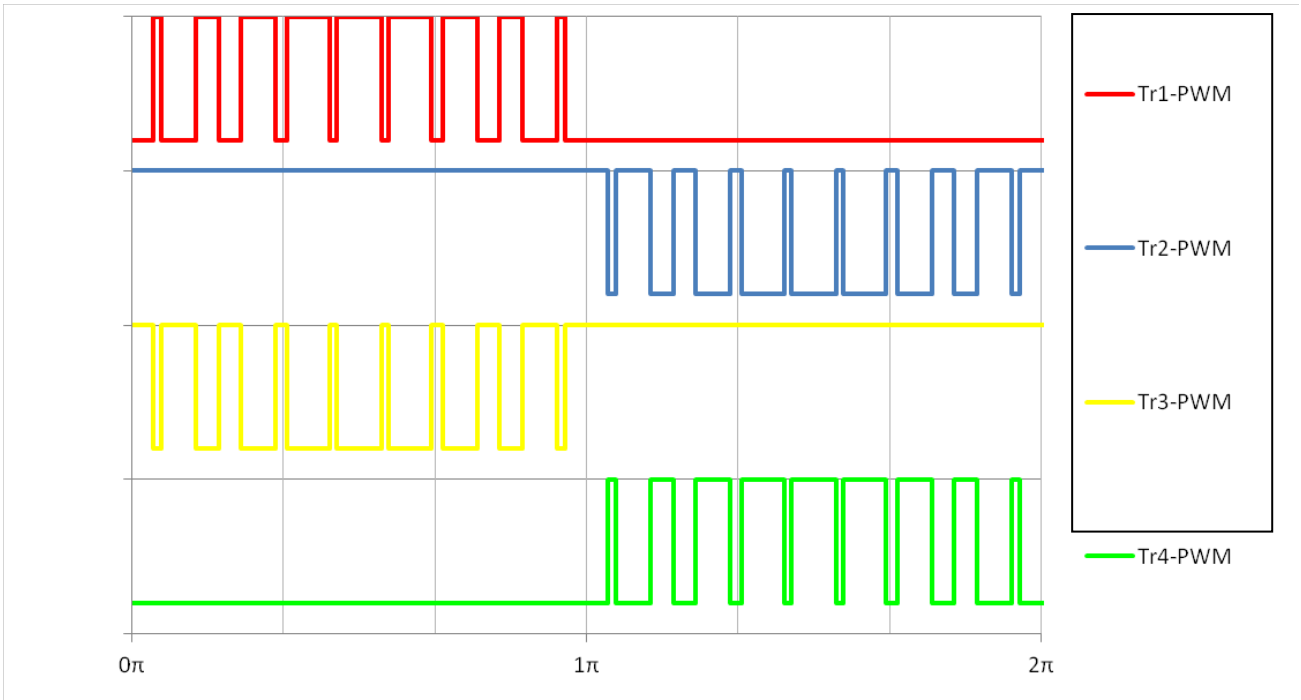
$$V_{U\text{-}V} = V_{U\_ref} - V_{V\_ref} = M\frac{V_{CC}}{2}\sin\theta - M\frac{V_{CC}}{2}\sin\left(\theta - \frac{2\pi}{3}\right) = \frac{\sqrt{3}}{2}M \times V_{CC}\sin\left(\theta + \frac{\pi}{6}\right)$$

Outut current Io is calculated by cos $\Phi$ from reference voltage.



The corresponding PWM Duty is simply calculated by comparing the count value of double up-down counter of micro controller with a reference voltage which is sinusoidal in this case.
Dead time as applied between Tr1 and Tr3, Tr2 and Tr4 in real PWM switching operations is not considered for the loss simulation.

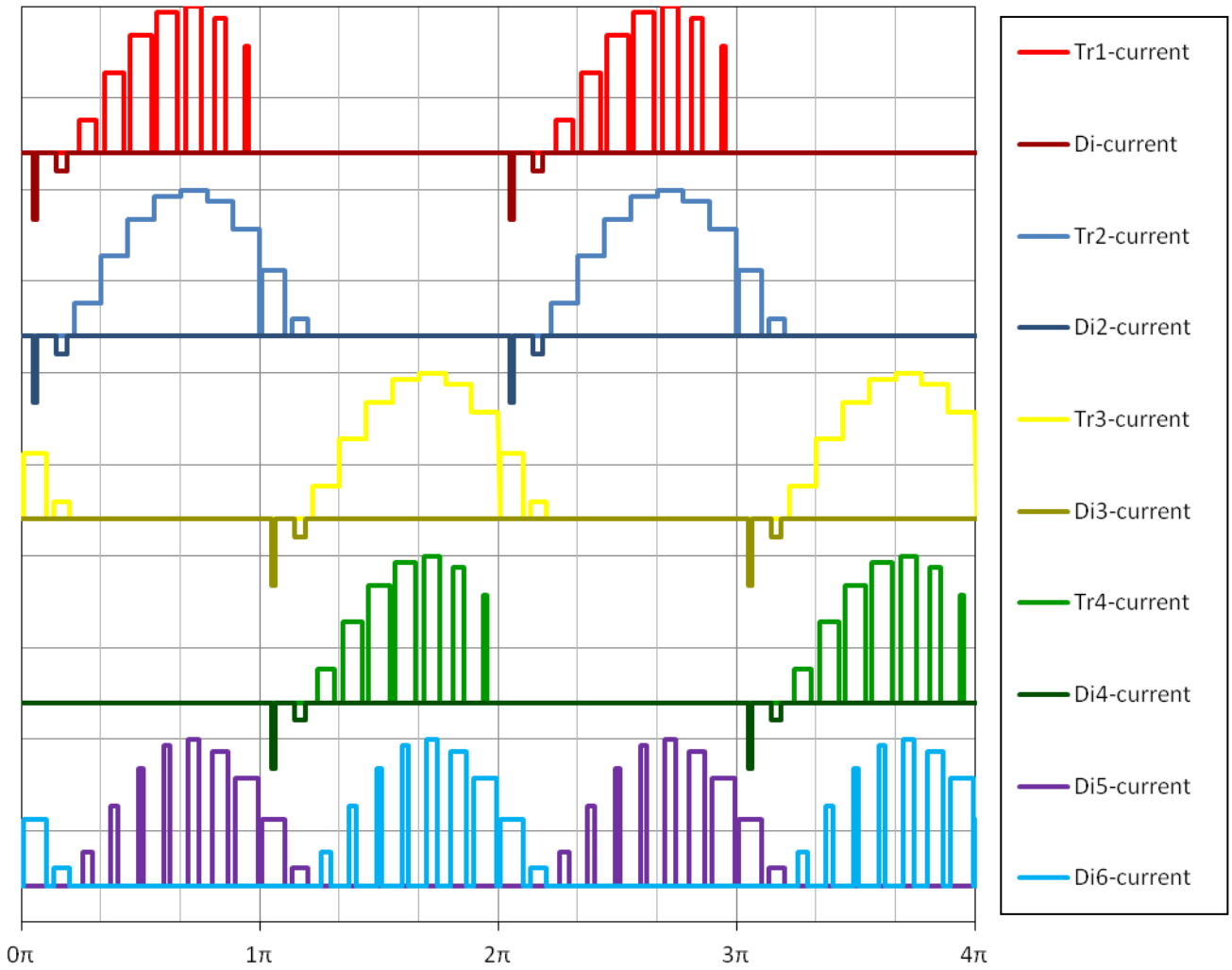


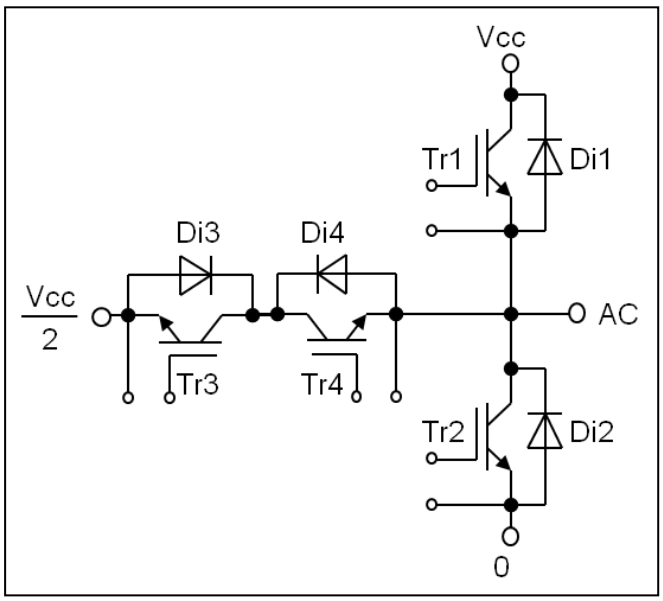
The power loss is calculated by the following analytical equation taking into account the interval mean values of the saturation voltages / forward voltage drops and currents being integrated / summed up over the entire cycle. By consideration of the duty cycle in that equation the mean power of each device can be calculated as follows:

$$P_{DC(\mathrm{IGBT})} = \sum_{phase=0}^{2p} \left( I_C \cdot V_{CE(sat)@I_C} \cdot Duty(on) \right) \quad , \quad P_{DC(FWDi)} = \sum_{phase=0}^{2p} \left( I_C \cdot V_{EC@I_C} \cdot Duty(off) \right)$$

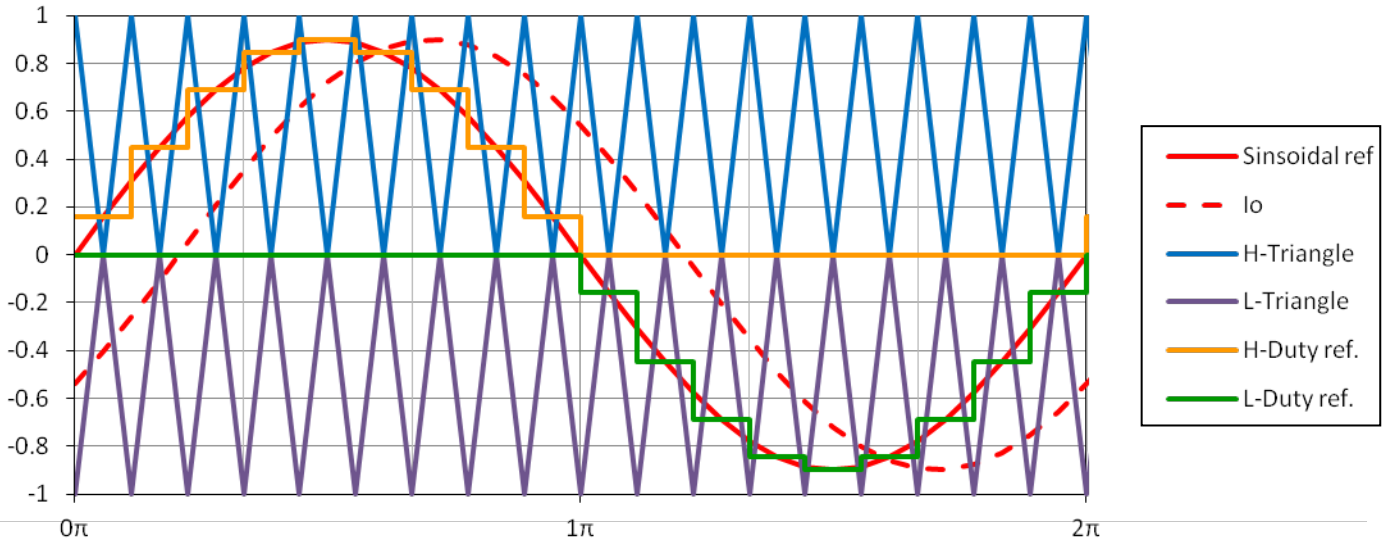
$$P_{SW(\mathrm{IGBT})} = \sum_{phase=0}^{2p} \left( E_{on@I_C} + E_{off@I_C} \right) \quad , \quad P_{SW(FWDi)} = \sum_{phase=0}^{2p} E_{rr@I_C}$$

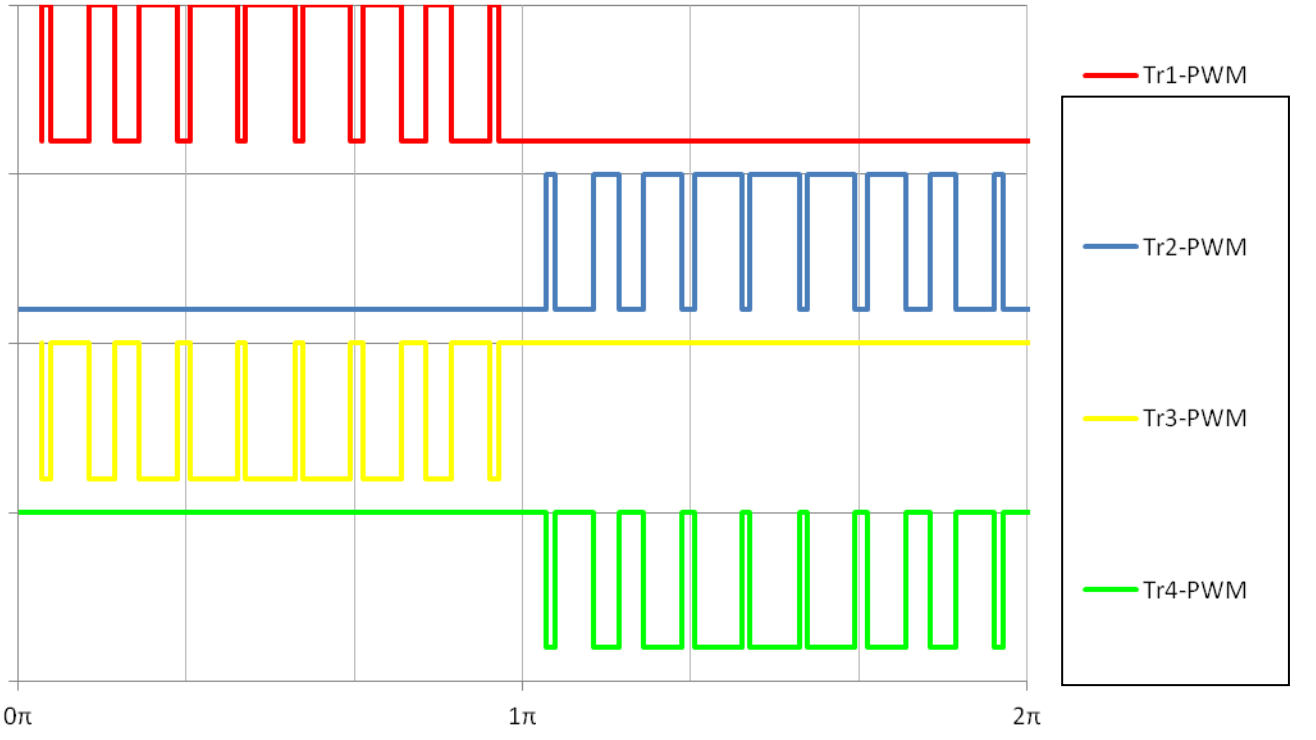


### 7.2.2 T Type (AC switch) NPC

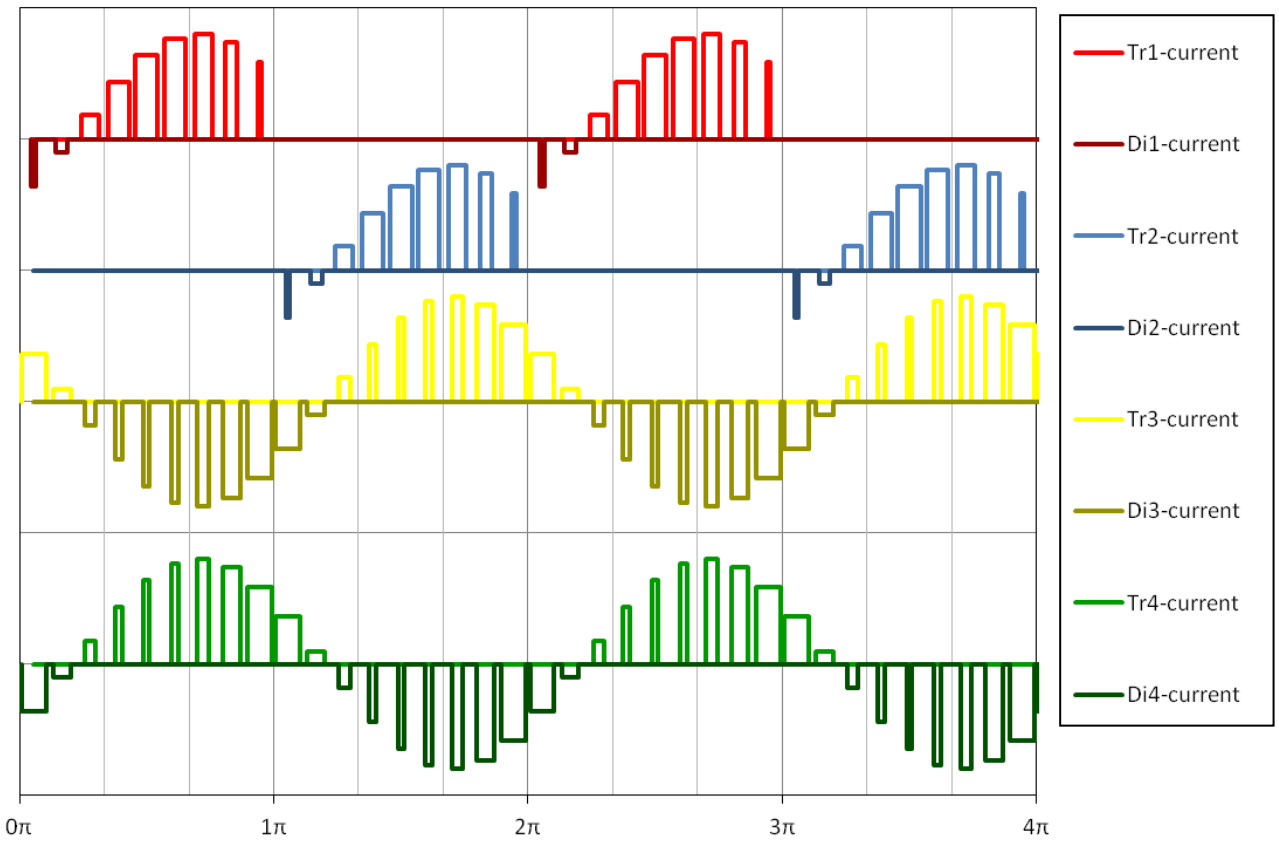



This is the one of modulation methods for sinusoidal output waveform of each phase by using 3-level inverter topology.
Free Wheeling Diodes (Di1 and Di2) are connected to IGBTs (Tr1 and Tr2) anti-parallelly, and these are factored in 2-level inverter connection and these chips are connected serially with IGBTs (Tr3 and Tr4) with anti-parallel Free Wheering Diodes (Di3 and Di4) as shown in right figure (one-leg).
The reference voltage for U, V and W-phase are shown in following figure same as 2-level inverter.
However, this circuit is comprised of number of power chips less than I TypeNPC 3-level inverter, the chops for Tr1, Tr2, FWDi1 and FWDi2 must be celected same as for 2-level inverter in withstand voltage.
Command has been changed to system which sinusoidal modulation (7.2.1) of I Type 3-level inverter circuit, Tr2 and Tr4 have been exchanged.



The current waveforms for loss simulation are shown as following figure.



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